Designing engaging non-parallel exertion games through game balancing

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A thesis submitted
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by
David Altimira

Supervisors:
Assoc. Prof. Christoph Bartneck
Assoc. Prof. Florian "Floyd" Mueller
Dr. Jenny Clarke
Dr. Gun Lee
Prof. Mark Billinghurst

University of Canterbury
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Abstract

Exertion games are digital games that encourage physical activity. Understanding how to make these games engaging is therefore important for promoting physical activity. Game balancing to mitigate wide differences in ability can help provide the right level of challenge and enhance engagement in social exertion games where players compete against each other. However, there is a lack of understanding of exertion game balancing design in non-parallel exertion games, where one player's actions influence the other's performance. Game balancing in non-parallel games should be able to moderate the influence each player has over the other, but current knowledge of exertion game balancing provides little guidance on how to achieve this.

This thesis aims to address gaps in exertion game balancing design by investigating the interrelationship between game adjustments, game balancing and player engagement. The thesis presents the different game adjustments that can be applied in exertion games, which I applied to the traditional table tennis game, a digital table tennis game and a digitally augmented table tennis game to study this interrelationship. It also explores differences in balancing between different game worlds and investigates how digital technology could be used as a resource for exertion game balancing design.

I designed four experiments to understand (i) balancing in different game worlds, (ii) static and dynamic sport equipment (i.e. bat and table) adjustments, (iii) the effects of altering players' performances such as their styles of play, and (iv) the relationship between the restriction on players' performance and player engagement. With (i) I found that game adjustments impact differently in different game worlds because the level of skill required to play the game (e.g. degree of accuracy of players' actions required to play) is different. However, in (i) I did not enhance player engagement, which is why I carried out a study (ii) to investigate game adjustments that could alter players' skills and players' performance in a more controllable way. This resulted in more effective adjustments for enhancing player engagement. With (iii) I investigated game balancing through altering the players' performances differently, and identified two ways that the restriction on players' performance can contribute in balancing the game: through the degree of challenge imposed by the restriction in place, and through the style of play the restriction encouraged from the more skilled players. To further investigate these study results I conducted another study (iv) to get deeper insight into the relationship between the restriction on players' performance and player engagement. The results of

the case studies including the game design considerations derived in (i), game design strategies derived in (ii) and (iii), and the understanding about the relationship between the restriction on players' performance and player engagement (iv), can help in making exertion games more engaging.

Although the findings and contributions were derived from the study of the table tennis game, I discuss how the findings can be applied to other exertion games. I hope the insights and contributions provided in this research can be generalised to inspire the design of future exertion games with the ultimate goal of encouraging people to engage in physical activity.

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Chapter I

Introduction

This thesis focuses on understanding exertion game balancing design and how it can enhance player engagement. In the following sections I first identify the need to understand exertion game design as a means to engage people to participate in physical activity. I then focus on game balancing, summarise the challenges of game balancing design, and describe the problem this thesis aims to tackle, the contributions made, and the approach followed.

1.1 Exertion games

Physical activity can provide health benefits such as helping address the obesity problem [50], which is increasing at an alarming rate [76], and reducing the negative effects of anxiety and depression [101]. This shows the importance of encouraging people to engage in physical activity. Understanding different ways to make physical activities more engaging should therefore be explored because this can increase the amount of exercise undertaken [92]. One way to make physical activity more engaging is through exertion interfaces and exertion games [63] [65].

Exertion games are digital games that use exertion interfaces to encourage physical activity [91], and an exertion interface is an interface that deliberately requires intense physical effort [63]. Exertion games have been developed in the latest generation of video consoles that use motion sensors, such as Microsoft's Kinect [104], Nintendo Wii [102] and PlayStation Move [82]. These video consoles support games that encourage physical activity, for example the "Wii Sports Resort" [103].

Exertion games can make physical activity more engaging [90, p.7]. For example, the physical activity can become goal-oriented [99], which can help in providing players with a clear challenge to achieve. According to the Flow Theory [30], this is necessary to provide the optimal experience. Moreover, using digital technology in physical activity can provide many benefits [8] [22] [29] [63] [66] [69] [67] [81]. The benefits include the provision of real time information about the user state [29], the provision of rapid feedback about the player's performance [8], the support of distributed participants [63] [66] [69], the mediation of one-to-one body interactions, reducing the physical risk during exercise [67], and the capability to compete with real and non-real athletes.

Baca et al. [9] also outlined the benefits of digital technology in sports and identified four areas where digital technology can be applied in sports. These areas are coaching, tracking (e.g. the Hawk-Eye system to decide whether a tennis ball is in or out), quantification/qualification of sports and physical activity, and leisure/entertainment.

Exertion games can be classified according to the game world they are played in. These game worlds differ in the amount of digital technology involved: virtual world, augmented reality and reality [105]. In this thesis I refer to exertion games belonging to each game world as digital physical games (exertion games played in a virtual world), non-digital physical games (exertion games played in the real world, i.e. traditional sports), and digitally augmented physical games (exertion games played in a real world augmented by digital technology).

To conclude, exertion games can make physical activity more engaging mainly because these games provide additional challenges for players to achieve, and the use of digital technology in physical activity can enhance player engagement. It is therefore important to understand exertion game design, and in particular to understand how to use digital technology to enhance player engagement in physical activity.

1.1.1 Exertion game design

Understanding exertion game design is important for enhancing player engagement. However, exertion game design that enhances player engagement is not easy because many factors can influence this. User engagement is defined as a quality of user experience characterised by challenge, aesthetic and sensory appeal, feedback, novelty, interactivity, perceived control and time, awareness, motivation, interest, and affect [73].

Although exertion game design is important, there is a lack of understanding of exertion game design [62]. Chi [27] advocated more research for increasing our understanding of how digital technology could be used to improve games. This thesis focuses on understanding exertion game design that enhances player engagement by altering the challenges the players have to face in a game through game balancing.

1.2 *Game challenges*

A game is a closed system with formal interactions from which conflict arises as players pursue goals, resulting in quantifiable outcomes [84]. The game's challenges result from these game-defined formal interactions and conflicts each player has to face.

The challenges a player has to face in exertion games can be analysed from two points of view. In one, we can analyse the challenges each player faces according to the amount of uncertainty of the game outcome [59] [60], such as the chance each player has to win a competition. In the other view, we can analyse the game challenges as the amount of physical and mental effort and skills required by the game [47]. Similarly, Sinclair [90] identified two different challenges for exertion game balancing: the intensity of the challenge (e.g. physical effort) and the game challenges defined by the success or failure of a player in a game.

Providing the right amount of challenge for players is important for enhancing player engagement [26] [47] [53] [70]. One approach to match players with different levels of expertise, yet providing the right level of challenge for players and enhancing player engagement, is through game balancing [12] [70].

1.3 *Game balancing*

Mueller et al. [70] defined "game balancing" as game adjustments that make the exertion activity not too strenuous, yet challenging for players, to optimize engagement levels. Therefore, game balancing aims to provide the right amount of challenge for players.

Understanding game balancing design can be important for players' health and for player engagement. The game balancing design is a process that involves the choice of the game adjustment to apply and the implementation of it (e.g. how the game adjustment will change during the game). Providing the right level of physical challenge can prevent exposing players to unhealthy levels of activity, for example when people with different fitness levels jog together [70]. In addition, when two players with different skill levels play a game, such as table tennis, the highly skilled player might feel bored playing against a less skilled player, and the less skilled player might feel anxious, as explained by Flow Theory [26] [30]. Similarly, the competitive position of a player against his or her opponent, such as the distance between the players' scores, can influence players' moods and self-esteem [98]. Player engagement can decrease when the game becomes more predictable [84], and other work has identified that competitors are optimally motivated when they feel they have about 50% probability of success [6]. In addition, certain perceptions of failure can have a negative impact on a player's self image and feelings of competence [49], and losing frequently might reduce the player's interest in the game [3]. After describing the importance of providing the right level of challenge for players, I describe the challenges of game balancing design and how the design can differ in different contexts.

1.3.1 Game balancing design

In this section I describe how the design can differ based on whether the design is for (i) single or multiple players, (ii) physical or non-physical games, (iii) digital or non-digital games, or (iv) parallel or non-parallel games.

Game balancing has been well studied in digital non-physical games [1, p.325]. Artificial Intelligence techniques have also been developed to adjust the challenge in these games. However, many of these techniques focus on single-player experiences. In multiplayer games, game balancing should be different because the challenges a player faces depend on other human opponents [11]. This can make game balancing more complicated [77].

Game balancing can be different between physical and non-physical games. In the context of physical games, there are additional challenges players have to face beyond those found in non-physical games, for example the physical effort and skills required [47]. The motivation to engage in physical games can also be different to non-physical games.

Game balancing can also be different between digital and non-digital games because of the support that digital technology can provide in balancing. For instance, digital technology can capture physiological responses of people [9] [10] [61] [70] [93], which can be used for game balancing and adjusting the intensity of a player while exercising [61] [70] [93]. In addition, digital technology can bring greater opportunities for adjusting the game, because digital elements, i.e. the players' avatars and the virtual environment, can be manipulated more easily than real elements, i.e. the players' skills and the physical environment. In a digital game it can be easier to assist the weaker player, for example by implementing target assistance techniques where a target is in a virtual world [12]. That is why, in non-digital games, game balancing is usually achieved by handicapping the more skilled player instead of enhancing the skills of the weaker player. Therefore the strategies for game balancing can be different from digital to non-digital games.

Finally, game balancing can also be different between parallel and non-parallel games. In non-parallel games each player functions as an obstacle that an opponent has to overcome in pursuit of the game's goals [68], such as in tennis. In contrast, in a parallel game, such as in bowling, the player's activities are performed independently and do not influence the opponent's activity [68]. When a player plays against another player to reach a goal, the player not only has to focus on the goal but also on thwarting the opponent [37]. Therefore, the influence of one player over the other can be important for player engagement. Game balancing might need to moderate this influence in non-parallel games. Although game balancing might need to be different between these two types of games, prior work on exertion game balancing focused mainly on parallel games, such as jogging, where a player's performance does not influence the other player's performance. This could be because commercial games mainly support this type of game, or because of the limitations of available technology for supporting player-to-player interactions [67]. As suggested by Mueller et al. [67] this contrasts with traditional sports, where interactions between players are more frequent.

To conclude, game balancing design can differ in different contexts. That is why an understanding of game balancing design in different exertion game contexts is important for designing well-balanced exertion games that enhance player engagement.

1.4 Problem addressed in this thesis

Game balancing design can differ in different contexts (see 1.3.1), but there is a lack of understanding of game balancing design that enhances player engagement in each of these contexts. In particular, there is a lack of understanding of (i) game balance design in non-parallel exertion games that moderates the influence of a player's actions on the other player's performance; (ii) how digital technology can support game balancing; and (iii) the interrelationship between game adjustments, game balancing and player engagement. This interrelationship exists. I describe the relation between game adjustments and player engagement, the relation between game balancing and player engagement, and the relation between game adjustments and game balancing.

The relation between game adjustments and player engagement: applying game adjustments can alter the challenge the players face, which is important for player engagement [47] [53] [70]. Moreover, game adjustments might impact upon factors beyond players' challenges that are relevant for player engagement, such as their sense of control or their interest [73].

The relation between game balancing and player engagement: game balancing can provide the right physical and mental challenge, as well as increase the uncertainty of the game outcome, which is also important for player engagement [84].

The relation between game adjustments and game balancing: game adjustments can equalise the chance of winning for the players [94], and balance players' skills or fitness levels, such as in jogging [70].

The main goal of this thesis is to provide an understanding about exertion game design that can take into account the aforementioned interrelationship. This includes an understanding about this interrelationship in exertion games, and how digital technology can support exertion game balancing design. In particular, this thesis emphasises the design of game balancing for non-parallel exertion games, such as table tennis.

Increasing this understanding will support game designers in improving the design of exertion games, and people will increasingly profit from the benefits of practising physical activity [62].

1.5 Scope

This section aims to clarify what is in and outside the scope of this thesis. **In:** This thesis aims to provide an understanding of exertion game balancing design for when a player competes against another player. The aim of game balancing in this thesis is to improve the player experience and enhance player engagement. **Out:** First, this thesis does not focus on game balancing in team games or single player games (i.e. a player against the computer). And second, although game balancing can motivate players to engage more in exertion games and thereby benefit from more physical activity, this thesis does not aim to provide more general insights into how to improve players' health or players' performances.

1.6 Contributions

From a theoretical point of view, this thesis makes a number of contributions:

- An understanding of the differences in game balancing between different game worlds, such as traditional physical games and digital physical games, and game design considerations therefrom.

- The provision of a set of game design strategies to understand:
  - How we could limit players' skills and still increase player engagement.
  - How we could use the explicitness of an adjustment as a resource for enhancing player engagement.
  - How we could moderate the influence of a player's actions on the other player's performance to enhance player engagement in non-parallel games.

- An identification of two ways that restriction of players' performance can help in balancing exertion games; through modulating the style of play, and through altering the challenge imposed in playing with a restriction in place. Also, the provision of two game design strategies therefrom.

- An understanding of:
  - The impact of inducing different styles of play and imposing different degrees of challenge on game balancing and player engagement.
  - The relationship between the restriction on players' performances and player engagement for designing engaging and balanced exertion games.

- An understanding of the interrelationship between game adjustments, game balancing and player engagement in exertion games.

- An understanding of how digital technology can support game adjustment design.

From the practical point of view, the contributions of this dissertation are the following ones:

- The design of different game adjustments that: support game balancing, mediate players' influence over opponents' performance, facilitate different game experiences, and alter player engagement.

- The design of two game adjustments, based on the insight gained in this research, that dynamically apply different game configurations to enhance player engagement.

1.7 Approach and thesis structure

This thesis aims to address the missing understanding about exertion game design that takes into account the interrelationship between game adjustments, player engagement and game balancing, with an emphasise on the design of non-parallel games. To address this missing understanding, this thesis focuses on the following research question: **How does game adjustment design affect game balancing and player engagement in non-parallel games?**

To answer the main research question I conducted a number of case studies to address the research question from different perspectives: studying balancing (i) in different game worlds (case study 1), (ii) when adjusting sport equipment (case study 2), and (iii) when adjusting the player's performance (case study 3 and 4).

The different case studies and the above perspectives were not planned beforehand. Each case study was designed based on the results from the previous conducted study in order to gain a deeper understanding of a particular finding. For example, (ii) aims to study game adjustments that provide more control of their impact on the player's performance than the game adjustments applied in (i) in order to understand if this could help enhance player engagement. In (ii) I show some of the benefits of altering the player's performance for game balancing. To gain more understanding about the effects of altering the player's performance on game balancing and player engagement I studied (iii).

With this approach I could not cover a full investigation of the different *game adjustment designs*, but I could investigate different aspects of balancing non-parallel games in depth, such as the relation between player's performance adjustment, player engagement and game balancing.

I formulated different research questions for each case study, each addressing the main research question from a different perspective:

- Case study 1 in chapter 4: **How does game adjustment design applied to different game worlds affect game balancing and player engagement in non-parallel games?**

- Case study 2 in chapter 5: **How does game adjustment design that alters the sport equipment statically and dynamically affect game balancing and player engagement in non-parallel games?**

- Case studies 3–4 in chapters 6-7: **How does game adjustment design that alters the player's performance affect game balancing and player engagement in non-parallel games?**

To answer the research questions I first establish the current understanding of game balancing (chapter 2). Second, I describe the designs of game adjustments for balancing the table tennis game, report the study results and evaluate the adjustments (chapters 4-7). Finally, I discuss the theoretical contributions of this thesis as derived from the study results (chapters 4-8). The contents of the following chapters are detailed below.

Chapter 2 reviews prior research into game balancing, player engagement and their relationship, and I identify gaps in the existing knowledge.

Chapter 3 describes the methodology followed and the motivation for the different game adjustment designs for each case study.

Chapter 4 describes the first case study. I studied how game adjustment design affects game balancing and player engagement in different game worlds: the traditional table tennis game and a digital table tennis game. The study results provide an understanding of the relationship between the level of skill required to play a game, game balancing and player engagement. I did not enhance player engagement in this study.

Chapter 5 describes the second case study, aimed at understanding how to enhance player engagement. I studied bat and table adjustments in both static and dynamic frequency updates for their impact on game balancing and player engagement in a digitally augmented table tennis game. I found the game adjustments to be more effective in enhancing player engagement than the game adjustments studied in chapter 4, and used the study results to derive a set of game design strategies to enhance player engagement.

Chapter 6 describes the third case study looking at how table adjustments can adjust players' performances by inducing different styles of play, and investigating its effects in game balancing and player engagement in a digitally augmented table tennis game. I identified two ways of how a restriction on players' performances (e.g. altering the allowed hit-ball location in table tennis) can contribute to balancing the game: (i) through altering the amount of challenge in playing with this restriction, and (ii) through altering the style of play on the more skilled players. Based on this understanding, I derived two further game design strategies.

Chapter 7 describes the fourth case study. I further investigated the study results obtained in the study described in chapter 6 by designing two table adjustments with different table configurations in each table adjustment in order to alter the style of play differently (by altering the table location), and to alter the amount of challenge in playing with the restriction (by altering the table size). By table location I mean the location of the playing surface area, and by table size I mean the size of the playing surface area. The study results were used to further the understanding of the relationship between the restriction on players' performance and player engagement.

Chapter 8 discusses the results, limitations of this research and describes how the contributions made could be generalised to other games. This chapter closes with suggestions for future research and concluding remarks.

Chapter II

Literature review

This chapter provides an overview of prior work and current theories that can help to design engaging exertion games and, in particular, to design engaging exertion games through game balancing. The approach taken for understanding game balancing from prior work is shown in Figure ??. First I review game design, including a review of player engagement and player experience, and theories for understanding player engagement, such as the Self-Determination Theory [34]. In the game design review, I pay attention to the game's challenges design, and social play design as they can be relevant for understanding game balancing design. Then I review exertion game design. Finally I review prior work on game balancing design, and conclude with research gaps identified from this literature review.

2.1 Game design

In this section I review prior work on game design, which includes a review of player engagement and player experience and how we could enhance player engagement. I also review game's challenges design and social play design as they can be relevant for understanding game balancing design that enhances player engagement in multiplayer games.

2.1.1 Player engagement and player experience

The user experience focuses on a user's perception and the responses resulting from the use or anticipated use of a product, system or service [14]. In games, the player experience is the player's perception and interaction with the game (actions and response obtained from the game) [84]. Understanding the player experience is important in game design for enhancing player engagement [16] [62] [77].

Enhancing player engagement is not easy as player engagement is a multifaceted construct [15] [21] [73], where diverse factors can influence it, such as the challenge, aesthetic and sensory appeal, feedback, novelty, interactivity, perceived control and time, awareness, motivation, interest and affect [73]. Other work also emphasised the importance of feedback given to players [21] [30] [95], the sense of control [21], and the perception of challenge [21] [26] [34] [51] [56] [59] [60] [30] [77] [89] [95], as important for understanding player engagement.

Lazzaro [56] identified three motives players have for playing beyond the perception of challenge, which are (i) the players' curiosity and the need for exploring, (ii) the emotions the game generates, and (iii) the need for playing with others. Similarly, other work also emphasised the importance of social play [21] [34] [32] [58] [83] [89] [95] [97], and the fantasy and the amount of curiosity the game generates to players [59] [60], as important for understanding player engagement.

In addition there are theories that support this prior work and they can also can help us in furthering our understanding about player engagement.

2.1.2 Theories for understanding player engagement

The theories I review are Self Determination (SD) [34], Uses & Gratification (U&G) [86], Flow Theory [30] and Technology Acceptance Model (TAM) [31].

Self Determination (SD) [34] proposes that human behaviours are determined by human needs for competence and mastery of optimal challenges (the need to take part in activities which allow us to feel capable and effective), autonomy (the need to experience freedom in the activities we choose) and relatedness (the need to feel a sense of connection to other people). These needs are also relevant to participation in sports [43].

Uses & Gratification was originally developed to explain the use of mass media (i.e. television) [86], but it has also been used to understand why people play video-games [89]. Sherry et al. [89] identified six reasons: competition, challenge, social interaction, diversion, fantasy, and arousal.

Flow Theory [30] states that the optimal player experience (the flow experience) is achieved when there is a balance between the players' skills and the challenges to be overcome. This theory has been studied and applied in game design and game analysis [26] [95] and in sports [47]; it has been related to enjoyment and motivation [17] [88]. Finally, Flow Theory has also been applied to explain engagement with technology [73].

The SD, Flow and U&G theories consider the players' perception of challenge as a key for designing successful games. It is then not surprising that commercial games pay attention to the design of the game's challenges. The "Super Mario 64" game tries to provide to the players a clear direction and purpose to their actions [84], key to achieving the Flow state. To achieve this, this game provides an increase in its challenges as players progress, and it tries to prevent the players from feeling lost or confused [84]. The "Crash Bandicoot" and "Jak and Daxter" games use dynamic difficulty adjustment in order to adapt the game's challenges to the players' skills [84].

There are other theories that can be useful for game design. The Technology Acceptance Model (TAM) [31] states that "usefulness" and "perceived ease of use" are two key factors that motivate the use of a technical system. This can be applied in game adjustment design. For example, a player might feel engaged with a game adjustment if this adjustment fulfils this player's goals, such as the enhancement of his or her skills. In addition, the way games implement the punishment and rewards that are given to players is also important. It has been suggested that the success of "World of Warcraft" came from the way advancement and rewards are distributed, which maximises players' commitment, following behavioural conditioning principles [35]. Similarly, "Half Life" uses a system of rewards and punishments based on principles of operant conditioning [84]. Understanding the design of punishment and rewards can be useful for designing game adjustments that need to give an advantage to one player and disadvantage another.

The above theories show two relevant factors for understanding player engagement: the perception of challenge and social play. Understanding the design of game's challenges and social play is therefore important, which could also inform how game balancing can be used to provide the right level of challenge in a game where different players play against each other.

2.1.3 Game challenges design

This section reviews prior work that provides insights into the design of a game's challenges as this is important for understanding game design that enhances player engagement (see 2.1.1) and, in particular, for game balancing design because game balancing aims to provide the right level of challenge for players (see 1.3).

As explained in 1.2, the game's challenges result from the interactions defined by the game, and the conflicts that arise as players pursue goals. To design the game's challenges it is important to look at the player-game interactions and the uncertainty of the game outcome [21] [59] [60] [30] [84] [98].

Flow Theory [30] provides insights into the design of these player-game interactions in order to enhance player engagement. According to Flow Theory, the optimal experience for the players can be achieved when they can concentrate on the task and goals, have control over their actions, are involved in the game tasks, are provided with clear goals and with tasks that can be completed, and are given feedback about the assigned task.

Other prior work emphasises the importance of "mastering" the different challenges players have to face [51] [98]. Players have fun only if they master a sufficient portion of the competitive game situations [98]. This mastery is important because success in a challenging competitive situation can be euphoric and increase motivation to continue onto the next competitive challenge [98]. The design of different achievable competitive situations for each player is therefore desirable. Finally, it is important to take into account the competitive position of each player relative to that of the other player (e.g. players' difference in score), and what tendency would be expected for the further progress of the competition [98]. This is important because it can affect the emotional state of the players, causing stress, enjoyment or frustration [98].

2.1.4 Social play design

This section reviews prior work that provides insights into the design of social play as this is important for understanding game design that enhances player engagement (see 2.1.1). This review is relevant because understanding the different aspects to take into account for social play design can be important to enhance player engagement when balancing multiplayer games.

Voida et al. [97] provided a set of guidelines for social play design. First, it is important to introduce intuitive mappings, e.g. from the players' body movements to the players' movements in the game. Second, it should also provide modes of play that downplay competition between players, thus fostering non-serious competition. Third, it should appeal to gamers with different gaming preferences. Finally, it is important to allow players with different skill levels to play together.

De Kort et al. [32] stated that social play influences player engagement and that it is characterised by the social affordances and the social context. Social affordances are the opportunities for verbal communication, awareness, and the ability to monitor people and each player's role. A game adjustment can alter the social affordances by making the adjustment explicit or implicit and thus alter the awareness of each player about his or her role, such as being advantaged or disadvantaged. The factors influencing social play are different for different social contexts [32], such as with co-located players or with players that play at different geographical locations (e.g. [66] [69] [67]). With co-located players the interpersonal distance or body orientation is important, whereas when players play at different geographical locations, it is the technology used to interact with each other that is important. The impact of social play on player engagement is also expected to be different depending on whom a player plays with. Playing with different players can elicit different levels of engagement [83].

Although social play is often desirable because it can lead to engaging player experiences, social play can also have negative effects on the player, such as shame, crowding or social pressure [32]. Moreover, social interactions and Flow experiences have been emphasised as having a potentially conflicting mechanism for player enjoyment [32]. While the flow experience is characterised by a deep involvement in the game task and a loss of awareness of the surroundings, in social play the awareness of the other players' actions is important. Therefore, one type of experience can impact negatively on the other.

After reviewing game design in games that do not require physical effort, I review in next section game design in exertion games.

2.2 Exertion game design

Prior work in understanding game design is insightful but this prior work was based on non-physical games. Understanding the differences between designing exertion games and other games that do not require physical exertion is important when applying previous understandings about game design to exertion game design. Prior work cannot be used to fully understand exertion games design for a number of reasons described below.

Our experience of the world is conditioned by our body and the interaction between our body and the world [38]. That is why the interaction of the players with the game and the players' experiences are different when players press buttons or when they use their full bodies to interact with the game. In particular, physical games need to consider the following aspects: (i) the players' bodies as the interfaces with the game, which might encourage different forms of engagement and new methods of measuring it [58]; (ii) the accuracy of new controllers that detect body movements [72]; (ii) the players' own goals, such as the completion of an exercise routine [19, p.311]; (iv) the physical effort as a determinant of the game outcome [65]; (v) the users' needs of physical exercise and the effectiveness of the game to meet these needs [91]; (vi) the body expressiveness, i.e. the body as a channel of communication, which might influence social play; (vii) the need to take into account the fatigue level, flexibility and coordination [77]; and (viii) the players' physical capabilities. In traditional non-physical digital games players develop strategies based on what they learn from the characteristics of the virtual world, whereas in physical games they have to adapt strategies which take into account their physical capabilities [40] [78]. For example, when designing systems for old people, it is necessary to accommodate possible physical limitations [40]. This shows that the design of physical games can be different from the design of non-physical games.

Based on these differences in designing physical and non-physical games, prior work provided insights on exertion game design taking into account the specificities of the new way of players' interactions with the game, e.g. full-body interactions. For example, prior work showed that the type of body movements the game involves can affect the way players are engaged [15]. This might suggest that game adjustments that alter the player's movements, such as when a game adjustment encourages changing the jogger's route to adjust the jogger's heart rate [70], can affect player engagement.

Similarly, theories described in 2.1.2 have been adapted to take into account the physical activity. For example, Self Determination in sports [43] or Flow Theory in sports [47]. In addition, Sinclair et al. [91] designed a dual flow model based on attractiveness (fun) using the standard flow model [30]. They defined effectiveness (meeting exercise requirements) as the balance of fitness (the body's skill in tolerating exercise) and intensity (the challenge of the exercise on the body).

After reviewing existing work on exertion game design, I explain game challenge design and social play design in exertion games.

2.2.1 Challenge design and social play design in exertion games

In exertion games, the perception of challenge and social play are also important for understanding player engagement [47] [78]. For example, Park et al. [78] transformed a fitness single player experience application into a social exergame in order to improve entertainment. However, the design of game challenges and social play can be different between exertion games and games that do not require physical activity. On one hand, exertion games can require physical effort and physical skills [47]. On the other hand, controllers that afford natural movements can influence social play because body postures can indicate players' emotions [16] [85]. Moreover natural movements allow co-present players to interact and communicate through the movement of their bodies during the play [58]. Full-body interaction can make the intentions of players more explicit and influence their behaviour. Lindley et al. [58] commented that in full-body competitive scenarios players might try to gesticulate less in order to hide their own strategy from other participants. Mueller et al. [63] also studied social play using exertion interfaces and their results showed that by using exertion interfaces players can get to know each other better, have more fun, become better friends and be happier in comparison to those using non-exertion interfaces. This shows how the design of game's challenges and the design of social play can be different to non-physical games.

I conclude with game design principles proposed by Campbell et al. [24] for the design of fitness applications. Game designers should (i) design the game core mechanics, i.e. the essential interactions that a player repeats during play, that are easy to learn but difficult to master in order to make learning and improvement both fun and challenging; (ii) use short-term micro goals to provide more frequent gratifications and to help players identify progress in the game; (iii) use marginal challenges, which are those challenges at the margin of the players' abilities; (iv) use rules that are not too restrictive (free play); and (v) use game mechanics which ensure players have an equal chance of winning (fair play).

After the review of game design and exertion game design, I review prior work in game balancing.

2.3 Game balancing design

This section summarises prior work about game balancing: game adjustments that make the exertion activity challenging to enhance player engagement. First I review Mueller et al.'s framework [70] that shows the different dimensions to take into account for game balancing design. From this framework, I review prior work that provides insight into game balancing design. Then I summarise the different game adjustments that can be applied for balancing exertion games. Afterwards I summarise developed strategies for game balancing, and I conclude with a section that describes the relationship between player engagement and game balancing.

2.3.1 Game balancing dimensions

Mueller et al. [70] presented a framework with different dimensions to take into account when designing balancing in exertion games: measurement, presentation, adjustment and control.

The measurement dimension focuses on what is sensed and measured, and it can be either the players' performances or the physical effort [70]. Heart rate has been the most measured physiological parameter in exertion games, such as in [70] [93]. However other measurements might be available, such as ECG, breathing rate or skin temperature.

Another dimension focuses on how whatever is measured and adjusted is presented to the players. The presentation can be either explicit, where the players are aware of the balancing, or hidden. The presentation can affect player engagement. Bateman states that one of the problems of balancing is that it can be too obvious, which might lead to feelings of artificiality [12]. Gerling et al. [41] related the degree of explicitness of each of the game adjustments to the impact of game adjustments on the player experience.

The third dimension is the adjustment. The adjustments can be analysed through the frequency of update (static and dynamic) [70] and how the difficulty is adjusted [1]. Balancing techniques were originally static, i.e. when difficulty is adjusted at the beginning of the game and it does not change. Afterwards, dynamic difficulty adjustments (DDAs) [45] that change the level of difficulty during the game started to be applied [1, p. 347]. Designing good DDAs can be difficult [90] and time-consuming to build and tune, but they can significantly enhance the player experience [1]. Game designers can also apply symmetric or asymmetric strategies [1, p. 324], in which the designers gives the same resources to the players (symmetric) or different ones (asymmetric).

The fourth dimension is control. The control of the game can come from the user or the designer [70]. When the designer allow the player to choose the level of difficulty at the beginning of the game (easy, medium and hard), the game adjustment is explicit and static and the control is with the player. In contrast, DDA is often implicit and the control is with the designer.

Mueller et al.'s work [70] provides an understanding on the different dimensions to take into account for game balancing design. It is therefore important to understand the design of each of these dimensions. In the next sections I review prior work on game balancing design. The work reviewed is based on the game world that balancing was applied to (digital or non-digital) and whether the research focused on physical or non-physical games. This highlights the opportunities for learning about game balancing from the different game worlds, and from physical and non-physical games.

2.3.2 Balancing digital non-physical games

Prior work in balancing digital non-physical games identified the different game adjustments that can be applied for game balancing, and also provided game balancing guidelines [1].

The different ways game adjustments can provide the right level of challenge are through adjusting (i) the intrinsic skill required (skills required to surmount the challenge with unlimited time, e.g. the strength of the enemies), (ii) the stress placed on the players by time pressure, (iii) the power provided (e.g. the strength of the player's character), and (iv) the amount of in-game experience (actual player skills) [1, p. 338]. An example is the "rubber band" adjustment implemented in racing games, where the players always remain in a competitive position regardless of their skill levels [90, p. 49].

Prior work on digital non-physical games [1, p. 324] define a well-balanced game as one where the players perceive the game as fair, where the more skilled players are rewarded, where each player has the perception of having the same chance of winning and where the player that falls behind in the game has a reasonable opportunity to catch up. However, little is known about the interrelationship between game adjustments, game balancing and player engagement.

2.3.3 Balancing digital physical games

Game balancing in digital physical games can be different to balancing in digital non-physical games (see 1.3.1). Here I describe prior work in multiplayer games because these types of games are more relevant for this thesis.

Prior work in game balancing mainly focused on improving player engagement through (i) allowing people with different abilities, such as able bodied and non-able bodied people, to play together [41]; (ii) allowing people with different fitness levels to exercise together [70] [93], or (iii) making the game more competitive [12] [94].

Prior work showed how game balancing was used to adjust the exertion intensity of the players, how this shaped the player experience and the impact that this had on the players' engagement [70] [93]. For example, Mueller et al. [70] measured the physical effort exerted by joggers by taking the current heart rate of the participants and their self-determined target heart rate. This was used to balance the fitness levels of joggers, which created a new social jogging experience. Similarly, Stach et al. [93] used a heart rate scaling mechanism where the performance of the players' avatars was based on their efforts relative to their fitness level, and they found that if players are aware of the adjustment it could impact negatively on the player experience. This prior work provided insights into how game balancing can impact on player engagement. However, the authors did not seek to understand the benefits of their proposed game adjustments compared to other possible adjustments such as the ones shown in section 2.3.5. Understanding the suitability of game adjustments in comparison to other adjustments can help in designing balanced and engaging games.

Gerling et al. [41] used a dancing game to be played in sedentary and motion-based control conditions to balance an able bodied player against a player in a wheelchair. They studied different game adjustments, such as score adjustment, adjustment of the precision of the input movements, and adjustment of the number of movements each player had to perform. This work shows the advantages of implicit over explicit balancing: they found that explicit game balancing could reduce self-esteem or the feeling of relatedness, whereas hidden balancing could improve self-esteem. In addition, this works shows the suitability of game adjustments: they concluded that score balancing was more suitable for closing extreme performance gaps between players, and adjusting the precision of the input movements was more suitable for reducing small differences and for asymmetric physical input (e.g. if one player uses a wheelchair). However, this work focused on a parallel game, and it does not provide an understanding on game balancing design in non-parallel exertion games

Bateman et al. [12] studied different target assistance techniques for helping players to aim in a Wii-shooting game. They found the assistance type affected the game score, and the players' differences in score affected the fun-ratings. They tested differences between the static and dynamic frequency updates in the player's score differential and the fun-ratings, but did not find any differences. Bateman et al. [12] also explained the properties of balancing methods that can cause disengagement, such as changing the gameplay or calculating the adjustments incorrectly. From this study we can learn the benefits of game balancing to make the game more competitive and more fun. However, this work also focused on a parallel game. Moreover, the authors applied game balancing in a virtual world to assist the weaker players. Therefore, this work provides little guidance about game balancing in other types of exertion games where there is not any virtual world to apply game balancing.

Prior work in exertion games balancing showed how game adjustments altered the players' body movements and physical exertion for game balancing, and that different game adjustments can influence the player experience differently. However, our understanding of the influence of game adjustments on player engagement is still incomplete because there are still game adjustments that have not been yet investigated (see section 2.3.5), and because most of the prior work focused on parallel games. This understanding is important when designing engaging balanced exertion games.

2.3.4 Balancing non-digital physical games

In non-digital physical games, such as traditional sports (e.g. basketball or soccer), there are fewer opportunities for balancing than in digital physical games because there is no virtual space in which to apply the balancing adjustments. For example, in traditional sports balancing, performance is most often measured and the score adjusted [70]. In sports like golf or basketball, different scoring rules can be applied to equalize the chance of winning, for example the handicap in golf [94]. There are also other ways to adjust the challenge and to provide a more balanced game, such as modifying the dimensions of the playing area (e.g. soccer field), adjusting the presence or attitude of an audience [47, p. 46], or limiting the skills of the more skilled players (e.g. playing with the non-dominant hand in table tennis). Finally, another method used for game balancing is the "ladders", where the system matches players with similar skill levels. The main drawback of this system is that it can prevent friends from playing together.

2.3.5 Exertion game adjustments dimensions

In this section I summarise the possible game adjustments that can be applied to balance exertion games. I classify the game adjustments into two dimensions (see Figure 2.1) based on the elements that determine the performance outcome in sports [4, p.6] [5, p.106] [23, p.16] and include other elements that might influence the perception of difficulty. I name these two dimensions as "internal" and "external" adjustments, borrowing these names from Weiner's model [5, p.108]. This extends the adjustment balancing dimensions of Mueller et al. [70] by explaining the different approaches to adjusting exertion games.

The internal adjustment dimension encompasses those balancing adjustments that are applied within a player in order to balance a game. These include adjusting a player's

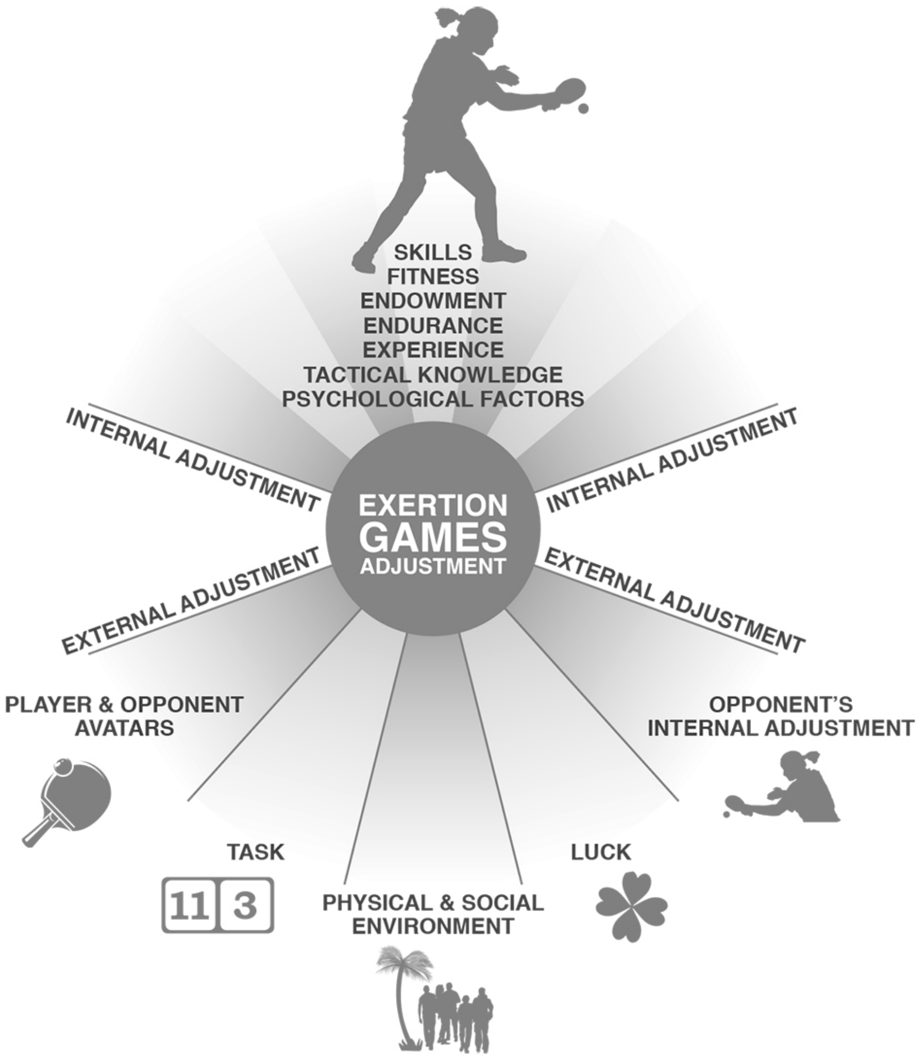

Figure 2.1: A two dimensional space based on internal and external adjustments for exertion game balancing

physical skills, tactical knowledge, strategic skills, endurance, flexibility, physical endowment, fitness, experience, and emotional or psychological factors such as mood, motivations, anxiety or confidence. I was inspired by the internal factors that determine performance when practising a physical activity [4, p.6] [5, p.108], and the examples of constraints used in the Game Sense (a method for coaching) that determine the player's perception of challenges [23, p.16]. An example of internal body adjustment is running an athletic course carrying extra weight and thus adjusting the speed that the athlete can run.

The external adjustment dimension encompasses those balancing adjustments that are applied externally to a player in order to balance a game. These include adjusting the physical environment (e.g. gravity, temperature, wind, humidity) or social environment (e.g. spectators' attitudes); the task (e.g. game rules, equipment such as racket size, score, time); the opponent's skills; the power of each player's avatar (in the case that players are represented by avatars), or luck (e.g. random game elements that a player might encounter and that can influence his or her performance such as the mystery boxes in the Mario Kart game). To define the external body adjustment dimension I was inspired by the work of Jackson et al. [47, p. 46] that defines different challenges and game adjustments in sports; the work of Adams [1, p. 338] that defines elements that compose the perception of difficulty in digital games; examples of environmental and task constraints used in Game Sense that determine the player's perception of challenge [23, p.16]; and Weiner's model [5, p.108] that explains the external causes of performance outcomes in sports (e.g. luck, task difficulty, opponents' performance). An example of an external adjustment is to give a score advantage to the less skilled player.

I have reviewed the different game adjustments that can be applied in exertion games. This can be useful for game balancing design. However, this review shows that prior work only studied a limited number of these adjustments (e.g. score adjustment in a dancing game [41]). Therefore our understanding of the effects of these game adjustments on game balancing and player engagement is limited.

After reviewing game balancing design in different game worlds and the different game adjustments that can be applied to balance exertion games, I review exertion game balancing strategies that can aid in game balancing design.

2.3.6 Game design strategies for game balancing

In this section I summarise two game design strategies that can help in game balancing design. Mueller et al. [70] provided a set of strategies to alter the player experience, such as facilitating empathy, for example by facilitating information about players' physical or emotional states. In another work, Gerling et al. [41] also proposed balancing strategies for accommodating extreme ability differences, for example a player with a wheelchair playing against an able-bodied player. These game design strategies are insightful, but are limited as they were derived from digital parallel games and from studies of a limited number of game adjustments. Exploring other game adjustments and other games (e.g. non-parallel games) can expand the available set of strategies for designing exertion game balancing.

To conclude the game balancing review, I review prior work that shows the relationship between player engagement and game balancing.

2.3.7 Player engagement and game balancing

In 1.3 I explain the importance of providing the right level of challenge for players to enhance their engagement. Providing the right level of challenge is the main goal of game balancing. Here, I describe prior work that supports this relationship between player engagement and game balancing.

Previous studies showed that game balancing can make the game more engaging for players with different skill levels. In one study, a balanced game was preferred because it gave more competition, challenge and excitement compared to an unbalanced game, and provided a greater feeling of success [52]. In another study, Bateman et al. [12] found that fun ratings were associated with the score differential for the assisted players. Although game balancing can enhance player engagement, the game balancing design is also important. For example, in one study, aggressive balancing techniques that led to more lead reversals in a racing game were the most preferred balancing techniques [25]. Another study showed the presentation of the adjustment (e.g. explicit or implicit) is important [41].

Prior work on game balancing showed that game balancing can be different in different game worlds (see section 2.3.2, 2.3.3 and 2.3.4), but there is a limited understanding of the effect of game adjustments in the different game worlds and of the opportunities digital technology can offer to extend current balancing techniques in sports. In addition, in exertion games, prior work focussed mainly on parallel games and included only a limited number of studies that aim to understand the relation between game adjustment and player engagement, and the suitability of game adjustments compared to other adjustments (see section 2.3.3). Finally, prior work showed that the design of game balancing can influence player engagement, such as when the game adjustments are explicit compared to when they are implicit (see section 2.3.3 and 2.3.7). Although game balancing is important, it is also necessary to further investigate the effects of game balancing design on player engagement in order to help in designing balanced and engaging games. In section 2.4 the research gaps this thesis aims to address are listed.

2.4 Research gaps

From the literature review, a limited understanding of the following aspects has been identified:

- How the different game adjustments that can be applied to exertion games affect player engagement.

- How the different game adjustments that can be applied to exertion games affect game balancing.

- The interrelationships between game adjustments, game balancing and player engagement.

- How this interrelationship differs in different game worlds, such as in traditional sports or digital sports.

- Balancing design in non-parallel games.

- How digital technology can be used as a design resource for game balancing design in exertion games, such as traditional sports.

2.5 Conclusions

This literature review has provided a current understanding of game design, exertion game design and game balancing design in order to enhance player engagement. I have reported the research gaps that I address in this thesis with case studies that investigate different game adjustments and the impact of these adjustments on game balancing and player engagement, to address the main research question: **How does game adjustment affect game balancing and player engagement in non-parallel games?** The different case studies address this question from different perspectives, studying balancing: (i) in different game worlds, (ii) by adjusting sport equipment, and (iii) by adjusting the player's performance. These perspectives aim to address the research gaps in section 2.4.

The choice of altering the sport equipment in (ii) was based on the findings obtained in the study (i) in order to obtain more control over the impact of the game adjustments on the player's performance. Finally, the choice of adjusting the player's performance in (iii) was based on the previous findings in this research, which showed that altering the player's performance can be suitable for game balancing in non-parallel games, but a greater understanding of the effects of altering the player's performance on game balancing and player engagement was needed.

Chapter III

Methodology

This chapter presents the research approach, which includes the study design, the data collection and analysis process, and the setup used for all the case studies. I also describe the game I used in the different case studies.

3.1 Study design

This section describes the game used for this research and the rationale of the different case studies conducted.

3.1.1 The game

I chose to use table tennis (see Figure 3.1) to study the game adjustments because it is a non-parallel game and enabled me to study the impact of game adjustments when a player plays against another player. Although there are other games that have these characteristics such as tennis, there are features of table tennis that make it more suitable for this thesis research.

- The table tennis game has digital versions, such as the Wii table tennis in the Wii Sports Resort [103], which allowed me to study the difference in game balancing between different game worlds (see case study in chapter 4).

- The setup of the table tennis game in a lab environment can be easier than other games, such as soccer, as it does not require a great amount of space.

- Prior work showed how digital technology can be integrated into this game to provide feedback about the players' performance [7], and to augment the game with visual digital information [46]. This is important because:

– Measuring the player's performance might help in understanding the impact of game adjustments on game balancing better.

– Augmenting the game with digital information can enable the researcher to investigate how digital technology can support game adjustment design, and to understand the unique opportunities digital technologies can offer for game balancing.

Figure 3.1: The table tennis game. The table was painted white to allow the visual projections to be displayed

In the next section I describe the rationale of the design of each of the case studies.

3.1.2 Case studies

This thesis is composed of four case studies that studied different game adjustments:

- Score and performance adjustment applied to different game worlds (case study 1).

- Bat and table adjustments (playing surface area size) in different frequency updates, i.e. static and dynamic (case study 2).

- Table adjustment (playing surface area location) (case study 3).

- Table adjustment (playing surface area size and location) (case study 4).

I describe the rationale of the design of each case study:

Case study 1: This case study reported in chapter 4 aims to address the research question **How does game adjustment design applied to different game worlds affect game balancing and player engagement in non-parallel games?** Prior work (section 2.3) indicates that game balancing might be different in different game worlds, and I identified a lack of understanding of the interrelationship between game adjustments, game balancing and player engagement in different game worlds (see 2.4). This study of the effects of score and performance adjustments on game balancing and player engagement in both the traditional and digital table tennis game addresses this gap. For performance adjustment I asked the more skilled players to play with their non-dominant hand, and for score adjustment I gave a six point advantage to the less skilled players in an eleven point game. I chose these two adjustments because they can be easily applied to different game worlds. In addition, these two adjustments aim to balance the game using a completely different approach, which could help to gain more insight into game balancing. In one, I altered the stronger players' strokes, and in the other I altered the game score without altering the players' actions during the game. For the score adjustment, I chose 6 point because is the rounded average of the possible score adjustments that could be used in an eleven point game. Finally, I acknowledge that these static adjustments might not be suitable for all possible players' skill levels, however the aim of the study was to understand the differences in balancing in different game words rather than providing the right level of challenge for players.

After the first case study, I selected the traditional table tennis game for the subsequent studies of game balancing for a number of reasons:

- Players in traditional table tennis require a higher level of skill than those playing in the virtual world (chapter 4). Therefore the difference in performance level between a skilled and a non-skilled player is likely to be greater. This is important to take into account for matching players with great different skill levels.

- I could not take an existing commercial game because of the limitations this would impose on the game adjustments I could apply.

- Although I could design my own digital table tennis game, this might create more difficulties in finding players with a great difference in skill levels because of the lack of experience of the players in it.

- One of the identified gaps in the literature review (see 2.4) was the understanding of how digital technology can be used as a design resource for game balancing in exertion games such as traditional sports. Choosing the traditional table tennis game allowed me to address this gap.

- Understanding game design and how to use digital technology to improve player engagement in existing sports such as table tennis is likely to make a greater contribution to our society than providing insights into a custom (digital) game.

Case study 2: This case study reported in chapter 5 aims to address the research question: **How does game adjustment design that alters the sport equipment statically and dynamically affect game balancing and player engagement in non-parallel games?** Since in case study 1 I could not enhance player engagement through game balancing, I chose to evaluate the bat and table adjustments statically and dynamically to alter the players' performances in a more controllable way and thus help in enhancing their engagement. The game adjustments induced different performances which helped in balancing the game. To get a deeper understanding about the influence of different performance outcomes on game balancing and player engagement, the third case study was designed.

Case study 3: This case study reported in chapter 6 aims to address the research question: **How does game adjustment design that alters the player's performance affect game balancing and player engagement in non-parallel games?** Based on table adjustments that alter the playing surface area location, I studied the effects of two players' performance adjustments. In one adjustment the playing surface area was placed close to the centre of the net, which induced a defensive style of play. Case study 2 showed that this style of play can help the less skilled player counter the strokes of the more skilled one. In the other game adjustment, the playing surface area was placed on one of the corners, which encouraged long strokes and a less defensive play than the other adjustment.

Case study 4: This case study reported in chapter 7 was designed to further investigate the results in chapter 6. Based on table adjustments that alter the playing surface area location and size I investigated the effects of different degrees of challenge imposed by the table adjustments and different style of plays induced by these adjustments on game balancing and player engagement.

3.2 Participants

For each case study I selected a sample of the population aged 18+ that had previously played with the game used in each case study. The participants were recruited from the university and from a table tennis club using flyers and were rewarded with a cafe voucher. Each case study in this research has a different number of participants because the design of each study (i.e. number of conditions) influences the number of participants required. However, in all studies I aimed to recruit as much participants as possible in order to maximise the statistical power.

Each participant completed an online pre-experiment questionnaire in which I asked them to rate their skill level and their frequency of playing in the case study (never, less than once a month, once a month, two to three times a month, once a week). I discarded players who had never played the game. The self-reported skill level was based on the following questions:

- Rate skill level as novice, beginner, competent, proficient or expert.
- Rate skill level as [0: low skill level to 100: high skill level].

I used the information from the pre-questionnaire to pair the participants, so that every pair had a difference in self-assessed skill level as large as possible. Self-assessment led to the possibility of creating pairs whose skills were actually quite similar, so I decided to discard any pairs whose difference in skill level was significantly smaller than that of the other pairs. This assessment was based on evaluating the final score differences in the conditions played; applying the Z-value test to detect outliers by looking at those Z values greater than or equal to 3 [2].

3.3 Data collection and analysis

In this section I describe the methods for evaluating the player's experience, and the methods for evaluating game balancing.

3.3.1 Methods for evaluating the player's experience

Understanding the player's experience is important in game design to enhance player engagement (see 2.1.1). Therefore, it is important to evaluate it in order to understand game balancing design that enhances player engagement. In this section I describe the approach taken in this thesis for evaluating the player's experience.

Mueller et al. [64] identified different methods for player experience evaluation in exertion games. In a post-playing evaluation, there are two main approaches: interviews and questionnaires. In-place player experience evaluation can be carried out through direct observation. For this thesis I therefore applied post-playing evaluation with interviews and questionnaires, and direct observation using a camera (see section 3.4) for the in-place player evaluation in order to observe the players' performances. To measure the player's performance I mainly took into account my observations of the player's stroke and ball movements and the player's reports in the interviews. In addition, I also used sensors to detect the ball-hit location during the game (see section 3.4.1) and measure the speed of the ball in order to obtain additional measurements about the players' performances.

Questionnaires have been popular in the study of player experience, and different constructs such as player engagement can be evaluated through them. There have been several questionnaires developed: social presence in game questionnaire [33] which focuses on players' relationships; user engagement scale [74]; perceived exertion scale [20]; participation motivation in sport and physical activity [42] [80]; Flow State scale [48]; NASA TLX (Task Load Index) [44], which measures participants' workload; and a scale to identify reasons that players play [28].

I evaluated player engagement instead of other constructs such as Flow, because player engagement, and in particular the chosen engagement model [73] and its engagement scale [74], have a more holistic view of player experience than other measures like Flow [74]. For example, player engagement includes focused attention, time perception and awareness, which are characteristics that make up Flow [75]. In addition, player engagement includes other factors, such as endurability (e.g. willingness to return to the experience), usability and novelty [73]. A holistic view of player experience is important because the Flow experience might not be the only type of experience that draws players to play games. The social play experience can also be important, but the mechanisms the social play use to enhance the enjoyability of the experience might conflict with the mechanisms of the Flow experience [32]. The chosen engagement scale is also suitable for this research because it is not tied to the videogames context and is therefore suitable for evaluating the player experience in both the traditional table tennis game and a digitally augmented table tennis game. Moreover, the survey scale has been verified statistically in terms of reliability and validity [74].

To obtain a player engagement score for each of the experimental conditions of this research, I first adapted the engagement scale to the gaming context (e.g. changing the statement "*The time I spent shopping just slipped away*" to "*The time I spent playing the game just slipped away*"), see Appendix B. For each participant and game condition, I obtained an engagement score by averaging the items of this scale. I excluded the items regarding the aesthetic factor because this was not relevant to the traditional table tennis game, and I kept the other factors of engagement: focus of attention, felt involvement, endurability, novelty and usability [74]. I chose to average the items of this scale rather than averaging the scores of each of the different factors because the contributions and weights of each of the factors in exertion games are still unknown. This is a limitation of this engagement scale in exertion games. As the engagement construct can be defined as a variable and measured with numbers, quantitative methods were suitable for the analysis of the player engagement scores [71, p.204].

The quantitative analysis of this engagement scale has the following limitations:

- Questionnaires have been criticised for their inadequacy to capture the player state during a game [64], such as the different stages of player engagement during playing time [73]. Moreover, in physical games, the exertion activity might affect the recall capability of the participants about the experience [64].

- Although this engagement scale has been validated, the validation was done outside the exertion game context [74]. Therefore, we cannot have absolute confidence about content validity, which assesses whether the full content of a definition (engagement) is represented in the measure [71, p.216].

- A quantitative analysis of the engagement scores does not provide information about the reasons for these scores.

- Traditional approaches to evaluate user experience in games can fall short in providing a complete story of the user experience when it comes to exertion [64]. Emotional change could occur not only from the game content but from the physical exertion the game facilitates [64].

To overcome some of these limitations I incorporated other forms of data collection: semi-structured interviews, which gave information about players' goals, frustrations and state of mind; and observations of players' performance during the game, which were used during the interviews for further discussion. The data from the interviews and observations is suitable for qualitative analysis [71, p.204]. Prior work emphasises the advantages of hybrid data collection; multiple channels of data collection can overcome the shortcomings of one channel [55, p. 330] and the resulting data may be of higher quality [55, p. 332]. The use of multiple indicators of player engagement can improve construct validity based on the idea that indicators of one construct act alike or converge [71, p.217]. Prior work in exertion game evaluation has also used a hybrid approach [63]. Finally, I also measured the reliability of the engagement scale to assess whether this method produced stable and consistent results for each case study, by calculating Cronbach's α using the approach described in [36].

For the qualitative approach I decided to use semi-structured interviews since this technique can be suitable to evaluate the effects of new technologies in practice [18], and therefore appropriate for evaluating the effects of game adjustments on players. The approach I followed was to define an initial set of questions and themes to be discussed with the players, which focused on understanding player engagement during the game. The initial planned questions were like the following: *"Recall the different conditions, tell me something memorable, something that you found enjoyable? In which condition? Why?"* (see Appendix C). From the themes that emerged from the players' reflections regarding their engagement, and my own observations about their performance such as the length of rallies, new follow-up questions were asked to understand their engagement better.

Interviews were audio recorded. This data was transcribed using a quasi-statistics method for the analysis, based on counting the number of times something is mentioned to measure the frequency of a phenomenon, and how events are distributed among categories of people [13]. I used this analysis to identify the most frequently reported player experiences and thus identify the more likely experience players have when the different game adjustments are applied. This provided a better understanding of the their engagement scores.

3.3.2 Methods for evaluating game balancing

I have taken into account the uncertainty of the game outcome because it is one way to evaluate the players' challenges in a game (see 1.2). In particular, I analysed the score differential between players in each match, and the win/lose ratio of each player in each game condition.

3.4 Setup

In this section I describe the equipment used, technological implementation and environment setup.

3.4.1 Equipment used and technology development

I used the following equipment: a table tennis table (case studies in chapters 4-7), the Wii Sports Resort digital table tennis game [103] (case study in chapter 4), bats with different head-sizes (case study in chapter 5), and a video projector mounted on the ceiling facing down towards the physical table tennis table (see Figure 3.2). The projector was used to project images onto the table surface, showing the boundaries of the different table adjustments to make players feel as if they were playing with an altered table (case studies in chapters 5-7), the location of where the ball hit the table, whether the ball hit outside the projected boundaries, and the difference in score between the players after each game point.

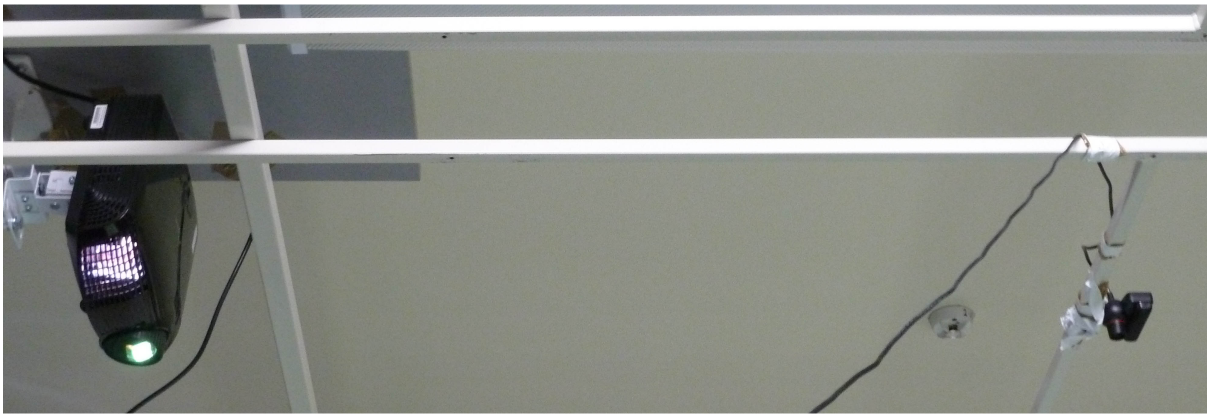

Figure 3.2: Projector (left) and PS3 camera (right) mounted on the ceiling

To locate the position of the ball when it hit the table, I used piezoelectric sensors placed underneath the table to detect hits, and a PlayStation 3 camera (120 Hz). I first applied the ball tracking system described in [46]. This system uses four piezoelectric sensors on the underside of each side of the table (see Figure 3.3), and evaluates the time difference of each sensor in detecting the hit. In my case this system did not work accurately and I decided to place a PS3 camera on the ceiling (see Figure 3.2) in order to capture the ball location. The new system detected when the ball hit the table using the system tracking technology described in [46], but instead of triangulating the time difference of each sensor hit detection, as in [46], the PS3 camera captured a snapshot of the table after the hit. The system applied image processing algorithms (e.g. background subtraction, contour detection, filtering) to the snapshot to locate the ball and determine its position.

This new system had some limitations. The lighting conditions in the playing area needed to be controlled, so I put curtains on the windows to stop sunlight entering the playing area. A second limitation was the frame rate of the camera. Although some shots, such as when a participant smashed and the ball moved very fast, could not be detected, the 120 Hz of the camera was enough to capture most of the hit-ball locations.

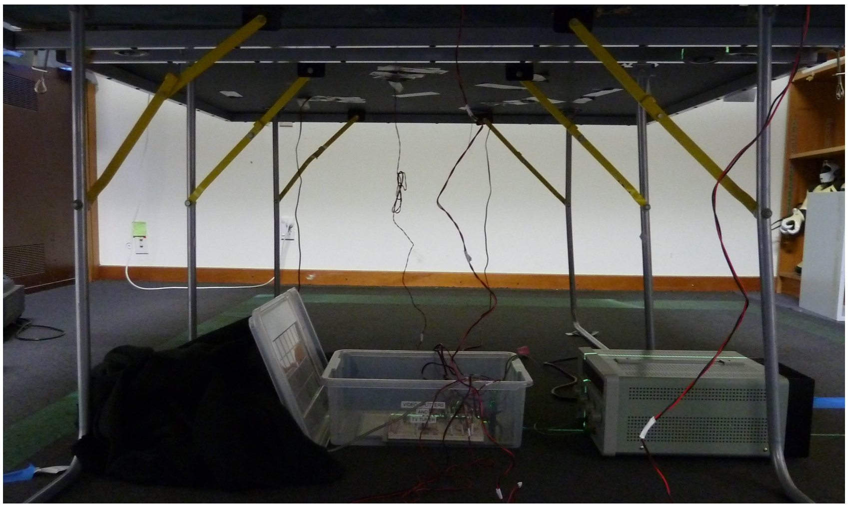

Figure 3.3: Piezoelectric sensors on the underside of the table to capture the ball-hit location

Finally I developed software (see Figure 3.4) that allowed me to interactively control the game and the information projected, i.e. set up the experimental conditions. In addition, this software allowed me to record the score of each player after each point, to start/stop each game point, to display the score on the table tennis table after each game point, to display the information about when the ball hit outside the virtual boundaries of the table, and to save all the information related to the game into a database. This included the game adjustment played and the players' scores, the average of strokes per point and per player, and the average ball velocity per player.

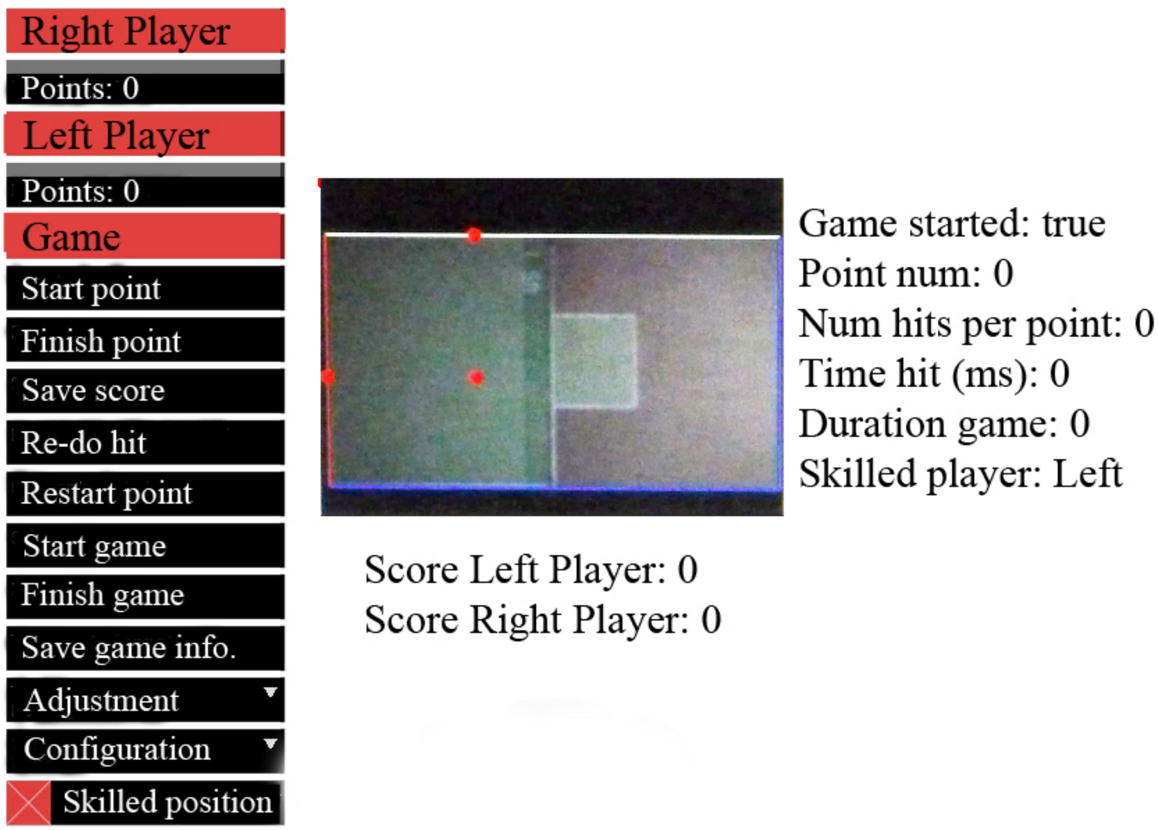

Figure 3.4: Software used in the different case studies

3.4.2 Environment setup

I set up a playing area, and a control and evaluation area (see Figure 3.5 and 3.6). The control and evaluation area is where participants filled out the questionnaires and were interviewed, and where I controlled the software, and took notes of my observations and the comments of the participants. Although I did not have direct contact with the participants while they were playing, I could follow the game through the visual information from the camera mounted on the ceiling (see Figure 3.2), which did not capture the participants but did capture the whole table and ball movements.

During the experiment the two spaces were separated with a curtain in order to prevent my presence from influencing the player experience. Similarly, when participants filled out the questionnaires, I moved into the playing area to avoid influencing their answers. I only entered the evaluation space when a participant needed help from me.

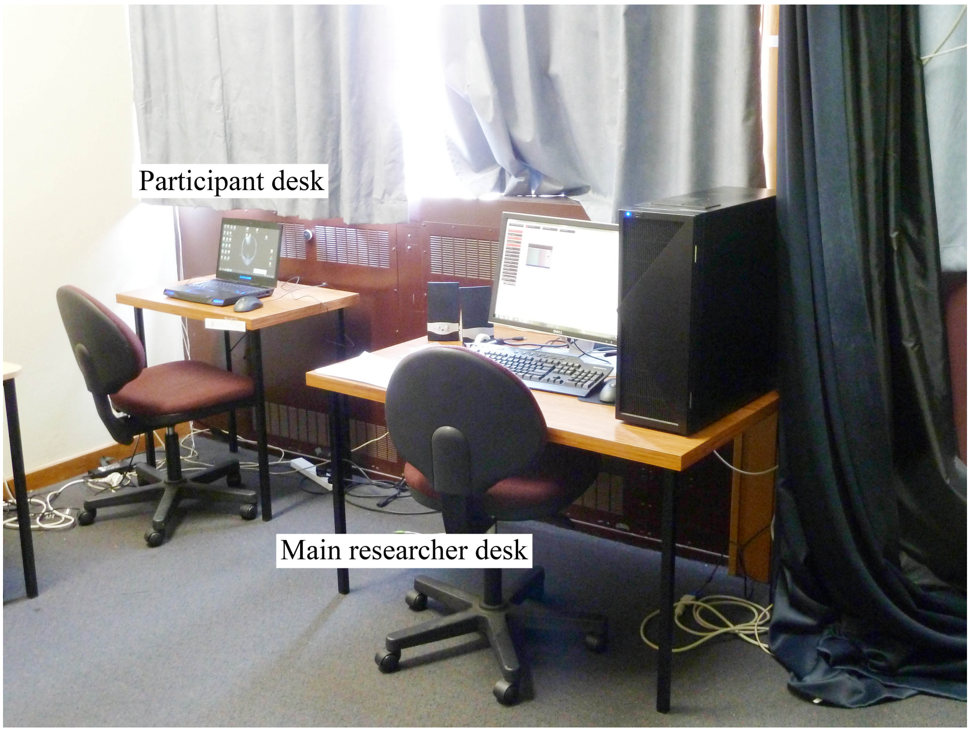

Figure 3.5: Control and evaluation area. The main researcher desk and a participant desk are shown

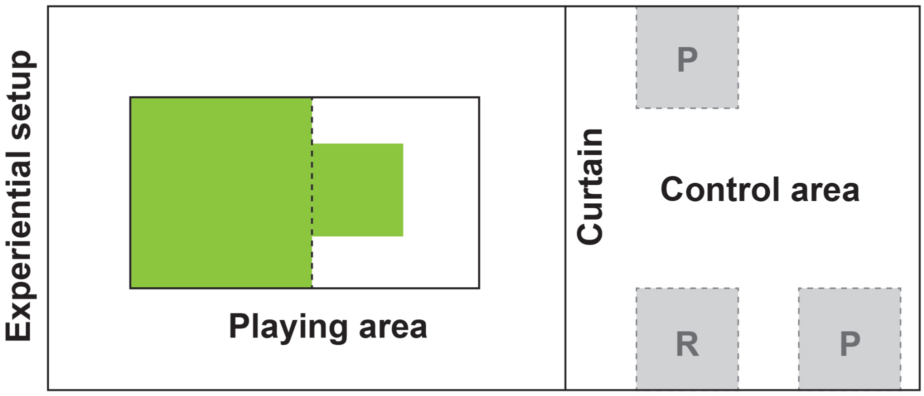

Figure 3.6: Playing, and control and evaluation areas. On the left there is the playing area and on the right the control and evaluation area. R is the main researcher desk. P are the participants desks

Chapter IV

Case study 1: Game balancing in digital and non-digital physical games

4.1 Introduction

The first case study aims to study the difference in game balancing between exertion games played in different game worlds, such as in the traditional table tennis game and a digital version of table tennis played with the Wii video console. Game balancing can be different in different game worlds because when players play a sportive activity mediated with digital technology, such as the Wii Sports Resort digital table tennis game [103], the challenges the players face are often altered in comparison to the non-digital game. For example, a digital table tennis game player might not require such precise body movements as in the traditional table tennis game. This might be caused by technical limitations, such as the accuracy of the sensors used, or by a designer choosing to make the digital game engaging for more people.

Understanding the differences in balancing between different game worlds is important because this might allow game designers to design adjustments (e.g. the score handicap) that provide the right level of challenge and make the game outcome more unpredictable, in each of the game worlds.

The main contribution of this work is insight into player engagement and game balancing when applying balancing adjustments to digital and non-digital physical games, and game design considerations therefrom. The study results show that when the level of skill required to play is altered, such as in Wii video console games that use digital technology to mediate the player interaction with a sport, the game adjustments should be designed differently. The rationale is that changing the required skill level to play a game affects the effectiveness of game adjustments (e.g. to balance the score) and the impact of the adjustments on player engagement.

The research question this study aims to address are the following: **How does game**

adjustment design applied to different game worlds affect game balancing and player engagement in non-parallel games? To address this question, I defined the following sub-questions (note that by "game adjustments" I mean the game adjustment studied: no-adjustment, score adjustment and performance adjustment).

- RQ1: Do game adjustments impact differently on game balance in non-digital physical games compared with digital physical games?
- RQ2: Do different game adjustments impact player engagement differently?
- RQ3: Do game adjustments impact differently on player engagement for the more skilled players compared with the less skilled players?
- RQ4: Do game adjustments impact differently on player engagement in non-digital physical games compared with digital physical games?
- RQ5: Regarding player engagement, is there an interaction effect among the game adjustments, game world played (digital or non-digital) and the player skill status (more skilled or less skilled)?
- RQ6: In what way do game adjustments impact on player engagement in non-digital and digital physical games?

4.2 *Methodology*

In this section I describe the game, the design of the study, the participants, the procedure and data collection and analysis. I do not cover aspects of the methodology described in chapter 3, but focus on those aspects in which this case study differs from the others.

4.2.1 The game

To investigate game balancing in non-digital physical games and digital physical games I used the traditional table tennis game and the Wii Sports Resort digital table tennis game [103] (see Figure 4.1).

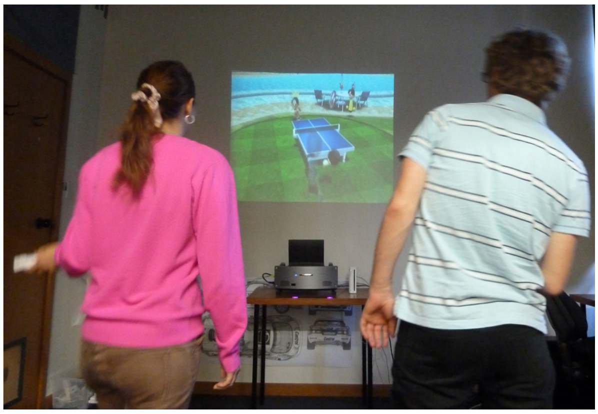

Figure 4.1: Case study 1. Non-digital (traditional) table tennis game setup (left) and digital table tennis game setup (right)

4.2.2 Study design

To answer the research questions, I defined a 3x2x2 mixed design with player engagement and final game score as dependent variables, and the following independent variables: game adjustment, players' skill status (more skilled or less skilled) and game world played (digital or non-digital table tennis game).

I defined the game adjustment as a within-subject factor with three levels: no adjustment, score adjustment and performance adjustment. I asked the participants to play an 11-point game in each table tennis match. For the score adjustment I gave a six point advantage to the less skilled participants because this is the rounded average of the possible score adjustments that could be used in an eleven point game. As this score adjustment is the average of all possible score adjustments, it might be the most suitable score adjustment for the average gap in skill level between players. For the performance adjustment I asked the more skilled participants to play with their non-dominant hand. I chose these two game adjustments because they can be applied to both digital and traditional table tennis games and they might balance the chances of winning of the players and thus might provide the right amount of game challenge. The order in which I imposed these three conditions was counterbalanced to avoid any order effect.

Although I acknowledge that explicit game adjustments can be less desirable than implicit ones because they might impact players' experience more negatively [41], game adjustments are often difficult to hide. This is often the case when balancing non-digital games, such as traditional sports. That is why I used explicit game adjustments. I also acknowledge that each of these game adjustments proposed might be more suitable in one game world than the other. However, this study did not aim to find the right level of adjustment, but to understand the differences between applying the same game adjustments in these two game worlds.

I defined players' skill status and the game world to be played as between subject factors. In every match one participant was assigned as "the more skilled player of the match", and the other as "the less skilled player of the match". This was determined by assessing each participant's skills using a pre-questionnaire prior to the main experiment (see 4.2.3). I chose to use a questionnaire because this allowed me to pair the participants with different skill levels and assign them to play the traditional or the digital table tennis game prior to the main experiment. Players' skill status determined who would be disadvantaged in the different game adjustment conditions.

4.2.3 Participants

I selected participants who had previously played traditional table tennis or digital physical games such as Wii sports games. I recruited 46 participants, mainly from the local university: 37 males and 9 females, whose ages ranged from 19 to 43 years with a mean of M=26.7 and a standard deviation of SD=4.9. Each participant completed an online pre-experiment questionnaire in which I asked them to rate their skill level [0: low skill level to 100: high skill level] and their frequency of playing (never, less than once a month, once a month, 2 – 3 times a month, once a week, 2 – 3 times a week, daily) with both the traditional table tennis game and the Wii table tennis game. I also asked about the frequency of playing other digital physical games such as other Wii sports games in case they were not familiar with our digital test game. I assigned each participant to the digital or the traditional game based on the information from the pre-questionnaire and paired him or her with another participant with the following objective: create pairs of participants in each game world with as large as possible a difference in skill level between the participants in each pair. Sixteen participants were assigned to play the digital game and 30 to play the traditional table tennis game.

For the participants assigned to play the traditional table tennis game, the more skilled participants had a self-reported skill level with a mean of M=66.89 and standard deviation of SD=17.02. In contrast, the participants grouped as less skilled had a self-reported skill level of M=33.73 and SD=18.88. Moreover, the Fisher's exact test showed the more skilled participants tended to play table tennis significantly more frequently than the less skilled participants ($p = .03$).

For the participants assigned to play the digital table tennis game, the self-reported skill level of the participants was not as useful for pairing participants because they tended to rate their Wii table tennis skill level quite low (M= 26.92 and SD=24.72). The participants seemed to be quite unfamiliar with the digital test game, and therefore I decided to separate them into skilled and non-skilled based on their frequency of play with other physical digital games such as Wii sport games. The familiarity of participants with the Wii mote input device (the tool participants used to play the digital test game) could provide a competitive advantage over those unfamiliar with this device. The Fisher's exact test showed the participants grouped as more skilled players tended to play digital physical games such as other Wii sport games significantly more frequently than those grouped as less skilled players ($p = .01$).

I evaluated whether the participants were paired correctly (see 3.2) by looking for any pairs whose skill level difference was significantly smaller than that of the other pairs in order to detect pairs whose participants had a similar skill level. In each game world I checked the results of the final score difference between the participants of each pair in the no-adjustment condition (see section 4.3.1), and I looked for outliers. I used the no-adjustment condition because is where I could better evaluate the real skill differences between the participants. As I did not find any outlier in any of the game worlds evaluated, I did not discard any pair.

4.2.4 Material and setup of the study

I used the equipment and technological implementation described in 3.4.1. However for this study I did not use any digital projection on the physical table surface as it was not required to detect the hit-ball location.

4.2.5 Procedure

Each pair of participants played for five minutes to warm up, followed by a competitive 11-point game in each game condition. After playing in each game condition I asked each participant to complete a questionnaire assessing player engagement. Afterwards, I interviewed the participants individually following a semi-structured interview.

4.2.6 Data collection and analysis methods

To evaluate game balancing, I evaluated the difference in score between participants in the different game adjustments: score adjustment, performance adjustment and no-adjustment. In this study I did not measure other parameters, such as the outcome of each stroke, because I could not retrieve these parameters from the digital game. To compare the difference in score between game adjustments, I applied the Friedman test in the table tennis game and in the digital game because the data was not normally distributed, and I applied the Wilcoxon test with Bonferroni correction for pairwise comparisons.

To evaluate player engagement I used the player engagement scale in [74] (see Appendix B), semi-structured interviews, and my observations about the participants' performance (i.e. player's strokes during the game) as described in 3.3.1. The reliability of the player engagement scale was high; Cronbach's-α=0.88.

The quantitative analysis of player engagement was used to answer research questions 2–5. I applied a repeated measures ANOVA (after validating its assumptions) with the game adjustment as a within-factor, and players' skill status and the game world played as between-factors.

The qualitative feedback was used to answer research question 6, which allowed me to understand the reasons for the reported levels of engagement. For the qualitative analysis I used the participants' reports from the voice-recorded semi-structured interviews and observations of participants playing the digital game and the traditional table tennis game in each of the game adjustments. The observations focused on different aspects of the game, such as game rallies and the number of participants' mistakes, and these were used in the semi-structured interview for the discussion of player engagement. I used a quasi-statistics method for the analysis of the qualitative feedback [13]. This allowed me to understand the engagement scores better.

4.3 Results

In this section I report the results of game balancing and player engagement.

4.3.1 Game balancing

RQ1: Do game adjustments impact differently on game balance in non-digital physical games compared with digital physical games? The analysis of the impact of the game adjustments on the final game score reported different results in each of the game worlds (see Figure 4.2).

In the traditional table tennis game, the Friedman test revealed significant differences between the final game score between game adjustments ($\chi^2(2) = 18.9, p < .01$). The Wilcoxon test showed that the final game score of the no-adjustment condition (M=5.19, SD=3.04) significantly differed from the score adjustment (M=–2.38, SD=4.47), $p < .01$, and from the performance adjustment (M=–0.94, SD=5.62), $p < .01$. No significant differences were found between the score adjustment and performance adjustment ($p = .33$). The more skilled participants won 94% (15/16) of the matches in the no-adjustment condition, 38% (6/16) in the score adjustment condition, and 56% (9/16) in the performance adjustment condition.

In the digital table tennis game, the Friedman test revealed differences between the final game score between game adjustments ($\chi^2(2) = 7.55, p = .023$). The Wilcoxon test showed that the final game score of the score adjustment (M=–4.0, SD=2.98) significantly differed from the no-adjustment (M=2.25, SD=5.04), $p = .049$, and from the performance adjustment (M=0.88, SD=4.05), $p = .017$. No significant differences were found between performance adjustment and no-adjustment ($p = .31$). The more skilled participants won 75% (6/8) of the matches in the no-adjustment condition, 13% (1/8) in the score adjustment condition, and 63% (5/8) in the performance adjustment condition.

To sum up, both score and performance adjustments helped counterbalance the advantage the more skilled participant had in the no-adjustment condition in both game worlds, with the exception of the performance adjustment in the digital game. In the digital table tennis game, the performance adjustment had a similar final score difference as the no-adjustment condition. Moreover, in the digital game, the score adjustment left the game unbalanced in favour of the less skilled participants. In contrast, in the traditional table tennis game, both score and performance adjustment seemed to balance the game score more than the no-adjustment condition.

4.3.2 Player engagement

The results of the engagement score (means and S.E.) are shown in Figures 4.4, 4.5 and 4.6. I report the results in response to the research questions below.

RQ2: Do different game adjustments impact player engagement differently? There were no significant differences in engagement among the three game ad-

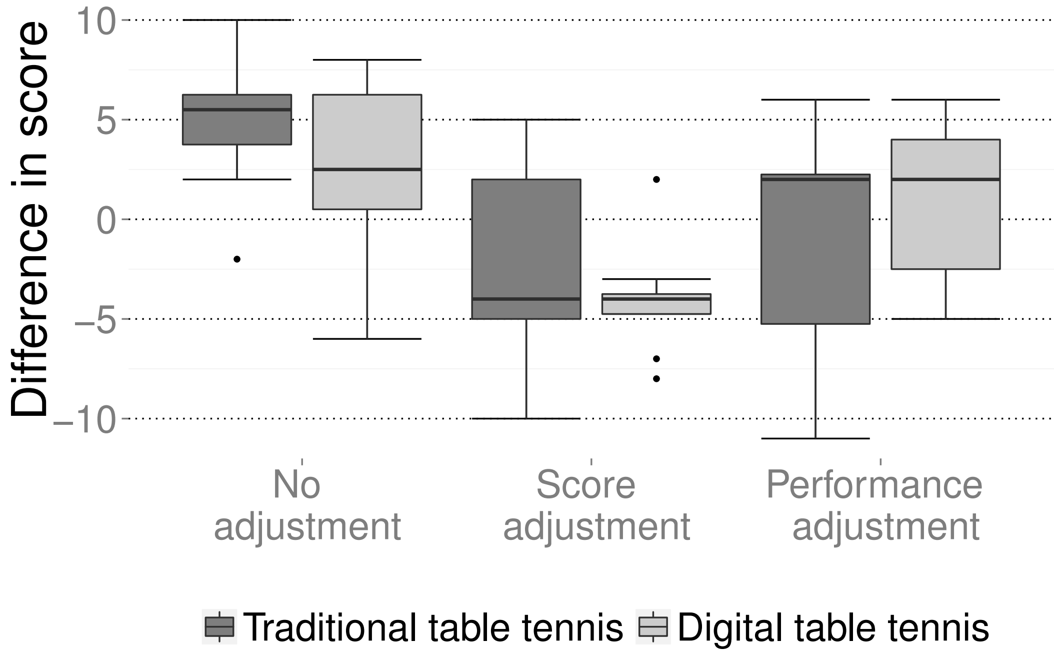

Figure 4.2: Case study 1. Difference in game score in three game adjustment conditions: no adjustment, score adjustment of six points and performance adjustment with the more skilled participants playing with the non-dominant hand. A positive score difference indicates a win for the more skilled participants, and a negative score indicates a win for the less skilled participants

justment conditions ($F(2, 32) = 0.24, p = .79, \eta_p^2 = .015$), see Figure 4.3.

RQ3: Do game adjustments impact differently on player engagement for the more skilled players compared with the less skilled players? There was no interaction effect between the game adjustment and the player skill status ($F(2, 32) = 1.27, p = .30, \eta_p^2 = .073$).

RQ4: Do game adjustments impact differently on player engagement in non-digital physical games compared with digital physical games? In the digital table tennis game participants reported lower engagement than in the traditional table tennis game in the no-adjustment and score adjustment conditions (see Figure 4.6). However, this tendency was reversed in the performance adjustment condition where participants in the traditional table tennis game experienced a decrease in engagement, while those in the digital game reported an increase in engagement (see Figure 4.6). This change of tendency in the performance adjustment condition was significant as shown in the interaction effect analysis between the game adjustment and the game world played

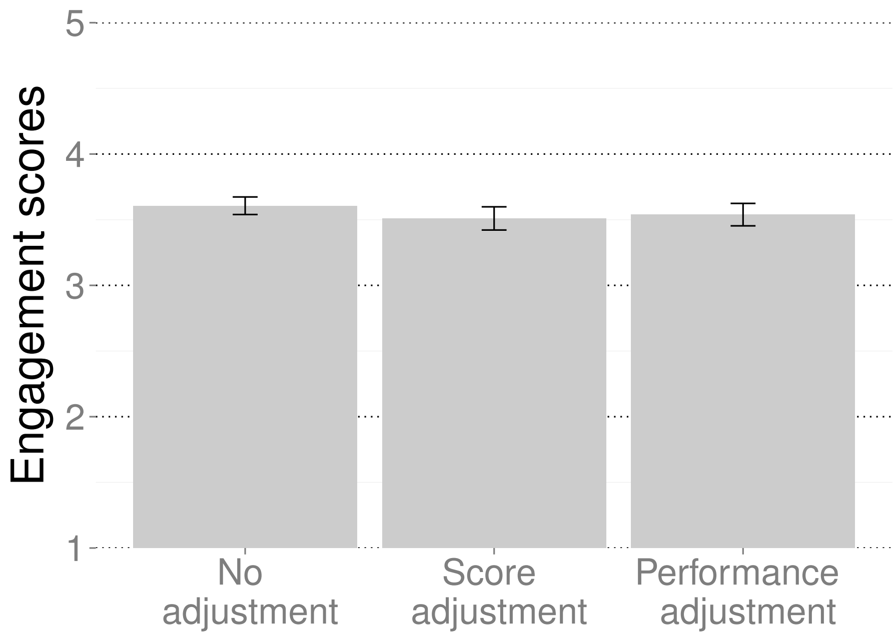

Figure 4.3: Case study 1. Means and standard error bars of the engagement scores [1-5] of the participants playing with the following game adjustments applied: no adjustment, score adjustment of six points and performance adjustment with the more skilled participants playing with the non-dominant hand

$(F(2, 32) = 5.06, p = .01, \eta_p^2 = .24)$.

RQ5: Regarding player engagement, is there an interaction effect among the game adjustments, game world played (digital or non-digital) and the player skill status (more skilled or less skilled)? The engagement scores for the less skilled participants, who were advantaged by the game adjustments applied, did not seem to change significantly among the game adjustments in both digital and traditional table tennis games (see Figure 4.4 and 4.5). The average of the participants' engagement score for each game adjustment varied from 3.55 to 3.77, and from 3.56 to 3.60 in the digital game and in the traditional table tennis game respectively. However the experience for the more skilled participants was different. The average of the participants' engagement scores for each game adjustment varied from 2.88 to 3.41, and from 3.37 to 3.88 in the digital game and in the traditional table tennis game respectively. In the traditional table tennis game the engagement scores in the no-adjustment and in the score adjustment conditions were similar, but they dropped in the performance adjustment condition (see Figure 4.5). In contrast, in the digital game, the scores in the no-adjustment and

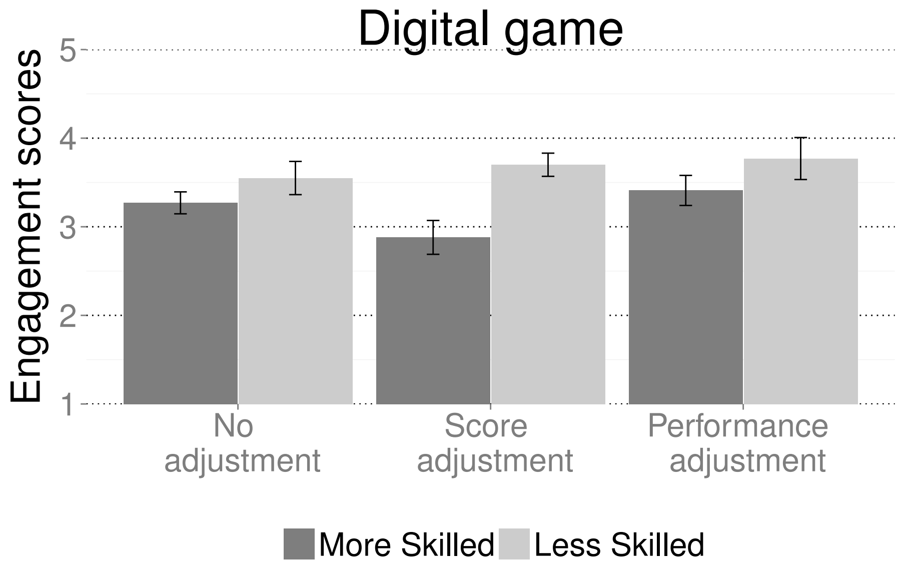

Figure 4.4: Case study 1. Means and standard error bars of the engagement scores [1-5] of the participants playing the digital table tennis game with the following game adjustments applied: no adjustment, score adjustment of six points and performance adjustment with the more skilled participants playing with the non-dominant hand. For each game adjustment the engagement reported by the more skilled and the less skilled participants is shown

performance adjustment conditions were similar but they decreased in the score adjustment condition (see Figure 4.4). This means the game world played influenced how the adjustments impacted the engagement scores of the more skilled participants. That is why there was a significant interaction effect of the game adjustments, game world played and the player skill status ($F(2, 32) = 4.45, p = .02, \eta_p^2 = .22$). To make this interaction effect clearer I conducted a planned contrast analysis to compare the conditions shown in Figure 4.7.

The contrast analysis showed that the engagement scores of the more skilled participants in the digital table tennis game were significantly lower in the score adjustment than in the other two game adjustments (Cr. 3: $b = -0.15, t(66) = -2.63, p = .01, r = .31$). In addition, this analysis also showed that the engagement scores of the more skilled participants in the traditional table tennis game were significantly lower in the performance adjustment than in the other two game adjustments (Cr. 8: $b = -0.16, t(66) = -2.98, p < .01, r = .34$). This contrast analysis supported the interaction effect analysis.

RQ6: In what way do game adjustments impact on player engagement in non-digital and digital physical games? The two most frequently reported factors

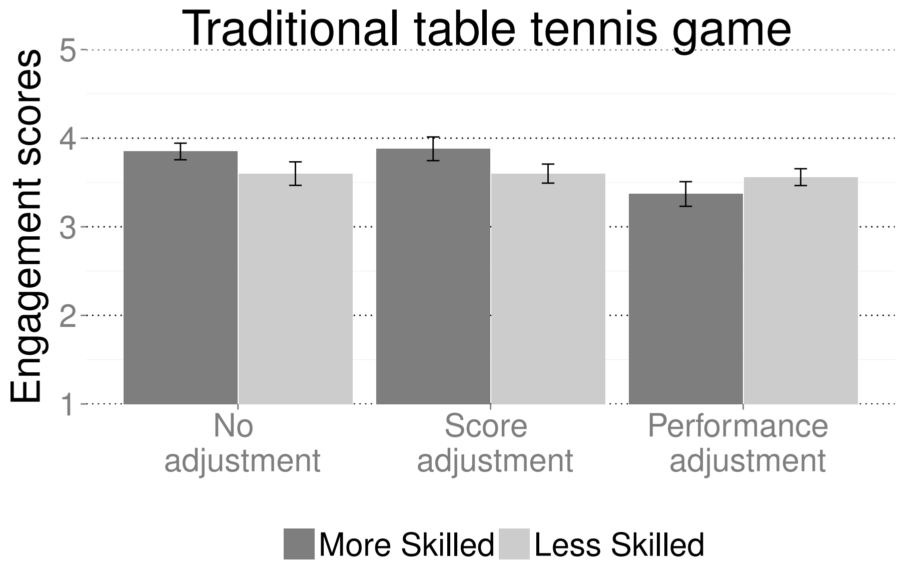

Figure 4.5: Case study 1. Means and standard error bars of the engagement scores [1-5] of the participants playing the traditional table tennis game with the following game adjustments applied: no adjustment, score adjustment of six points and performance adjustment with the more skilled participants playing with the non-dominant hand. For each game adjustment the engagement reported by the more skilled and the less skilled participants is shown

that were identified to influence player engagement were the perception of challenge and the perception of unfairness.

Factor influencing player engagement: the perception of challenge

Game adjustments had a different impact on players' challenge, which might have influenced their engagement scores. According to the interviews, the less skilled participants reported a less challenging experience when playing with a game adjustment. However, the more skilled participants (38% of those playing in the digital game and 56% of those in the traditional table tennis game) reported that the score adjustment increased their concentration, as they tried to get points faster. Additionally, the more skilled participants (50% of those playing in the digital game and 78% of those playing in the non-digital table tennis game) also pointed out that playing with the non-dominant hand changed their game strategies because they had to focus on controlling the table tennis racket or Wii controller. For example, one participant playing in the traditional table tennis game reported: "*I need to be more careful in the game (. . .). I have to think more when I move*

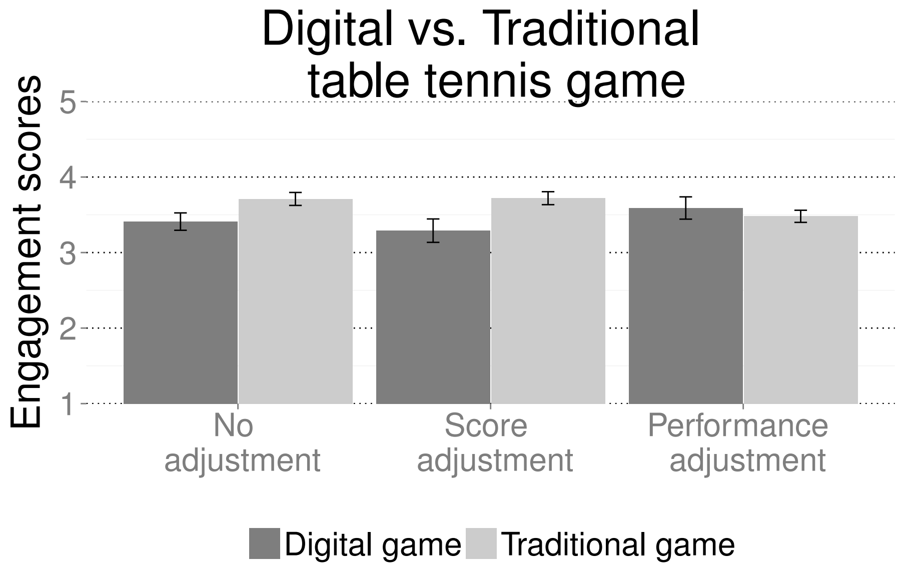

Figure 4.6: Case study 1. Means and standard error bars of the engagement scores [1-5] of the participants playing the traditional table tennis game and the digital table tennis game with the following game adjustments applied: no adjustment, score adjustment of six points and performance adjustment with the more skilled participants playing with the non-dominant hand

my hand to actually (...) you know (...) calculate where I should place my hand (...)". Of the participants in the traditional table tennis game playing with the non-dominant hand, 44% went further, stating that this adjustment changed their game goals.

Based on my observations of the participants playing with the non-dominant hand in the traditional table tennis game and the number of participants' errors I noted, participants felt quite uncomfortable owing to the lack of sense of control, which could partly explain the decrease of their engagement in this adjustment. To summarize, for the more skilled participants, the score and performance adjustments impacted on their challenges differently and the strength of the impact seemed to be higher in the traditional table tennis game than in the digital game.

Factor influencing player engagement: the perception of unfairness

From participants' reports in the semi-structured interviews, their engagement scores were also influenced by their perception of unfairness. For example, one participant, who played with a score advantage in the traditional table tennis game, answered the following when asked which was the preferred condition: "*The fair one, the no handicap (...) I felt*

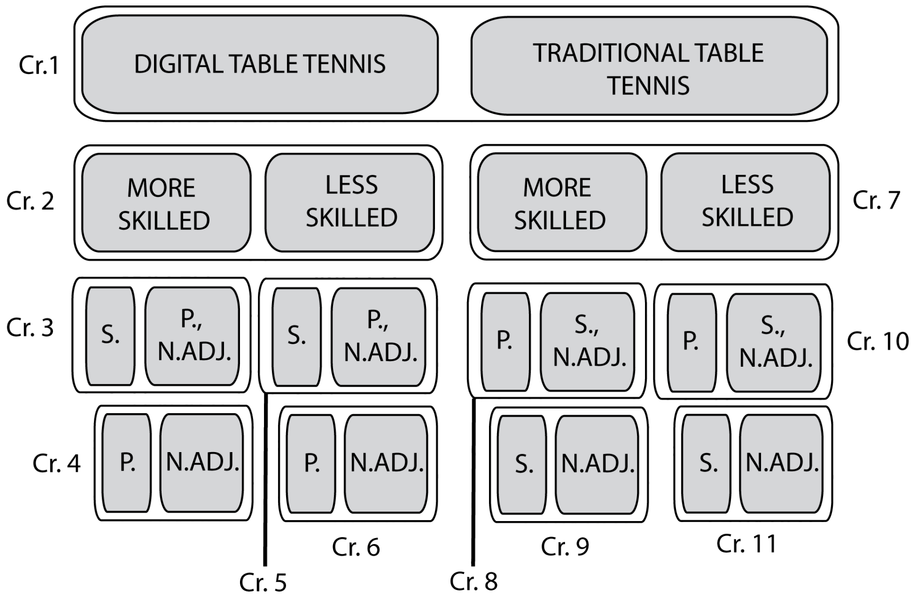

Figure 4.7: Case study 1. Planned contrast analysis of engagement scores. For example, Cr. 1 (Contrast 1) compares engagement scores between digital table tennis and the traditional table tennis; Cr. 2 compares the engagement scores between the more skilled participants and less skilled participants, who played in the digital table tennis game. 'S.' refers to the score adjustment, 'P.' Refers to the performance adjustment, and 'N.Adj.' refers to the no-adjustment condition

bad I won because of the handicap, it was not very satisfying". Another participant who played with a disadvantage in the digital table tennis game answered the following when asked why the game adjustments provided a less engaging experience although providing a higher amount of challenge: "*Because it was not fair, so (...) in that case, I did not want to play. If it is not fair, I do not want to play, I do not want to enjoy the game*".

4.4 Discussion

This study shows how game adjustment design applied to different game worlds of the table tennis game affect game balancing and player engagement. I found that game adjustments can impact differently in games played in different game worlds. In this section I discuss the implication this has on game balancing design.

Using digital technology to play a physical game such as table tennis often simplifies the player-game interaction in comparison to the traditional table tennis game. The degree of simplification might depend on several factors, such as the design of the game, how the technology is implemented, and the accuracy of the sensors used. The two test games used in this study are examples of how digital technology can lower the accuracy required by the players and how it can adjust the level of skill required to play the game. For example, it is can be easier to make the ball spin in the digital game with a small hand movement than in the traditional table tennis game. I argue that when this happens, game adjustments for game balancing should be designed differently. For example, this study showed that playing with the non-dominant hand affected the score of the participants playing in the traditional game more than those playing the digital game (see 4.3.1). Therefore, altering the level of skill required to play a game can affect the effectiveness of game adjustments (e.g. to balance the score). Moreover, this study shows that it can also affect player engagement.

The influence of game adjustments on player engagement was different between the more skilled participants and the less skilled participants. While the less skilled participants did not report significant changes in engagement among the conditions in any of the game worlds played, the more skilled participants tended to be more disengaged in the score adjustment than the other game adjustment conditions in the digital game. Similarly, the more skilled participants tended to be more disengaged in the performance adjustment than the other game adjustment conditions in the traditional table tennis game.

From the observations of participants playing, I hypothesize that the more skilled participants might have played slightly more “sportingly” in the no-adjustment condition, i.e. they did not use all their skills to play against their opponents. This might have reduced the impact they had on their opponents’ performance and engagement, which might partly explain the lack of significance difference of the engagement scores between the game adjustments of the less skilled participants.

Regarding the more skilled participants’ disengagement, I used the results of the interviews and direct observations during the play to derive the following disengagement factors.

4.4.1 Disengagement factors

From the study results I derived two key factors of disengagement that I named “unexpected physical challenges” and “unacceptable competitive advantage”.

Disengagement factor 1: unexpected physical challenges

The more skilled participants tended to disengage when playing with the non-dominant hand in the traditional table tennis game. Playing with the non-dominant hand changed their game goals and strategies (see 4.3.2) because it increased the physical challenge of manoeuvring the table tennis bat. They were not used to playing table tennis with this type of physical challenge and experienced a decreased sense of control, which made the game frustrating, leading to disengagement. These results about player disengagement align with the claim of Park et al. [78] that the more intuitive the game interactions, the faster the players engage in gameplay. Other work also emphasized the importance of the game controller (which in our case was the bat and the Wiimote) in player engagement [16]. These results also remind us that while providing a balance between skill level and challenge level is important [30], there are other factors that contribute to player engagement, as described in [74]. These other factors are important to take into account for the design of game balancing.

However, in the digital game, participants using the non-dominant hand did not experience decreased engagement. I believe the reason is that the digital game required a lower skill level to play and therefore playing with the non-dominant hand did not affect the participants as much as in the traditional game. The study results show that more participants reported an increased degree of challenge when playing with the non-dominant hand in the traditional table tennis game than when they did in the digital table tennis game (see 4.3.2). From these results I derived a game design consideration, which designers should be aware of when designing game balancing.

Design consideration: Increasing the required skill level to play can increase the impact that a performance adjustment has on the players. In this scenario the game adjustment can introduce an unexpected physical challenge, which game designers should be wary of as it could lead to player disengagement.

Disengagement factor 2: unacceptable competitive advantage

The more skilled participants tended to disengage when playing with a score disadvantage in the digital table tennis game; however, the more skilled participants did not disengage with the same score adjustment in the traditional table tennis game. I believe this is because the participants did not accept the disadvantage in the digital table tennis game because they felt it was excessively high (see 4.3.2). The study results also showed that more participants reported an increased degree of challenge when playing with a score disadvantage in the traditional table tennis game than in the digital table tennis game even though they had fewer possibilities to win in the digital game (see 4.3.1). This can strengthen the hypothesis that participants disengage from the game owing to the perception of a great disadvantage in the digital table tennis game.

The digital game required a lower skill level to play and therefore the performance of the two participants was more similar in the digital game than in the traditional one. This can explain why the digital game required a lower score adjustment than the traditional game, and why a six point adjustment overbalanced the digital game. Gerling et al. [41] previously pointed out that overbalancing might affect the experience of the stronger player. Similarly, Stack et al. [93] claimed that the fun of the game can be influenced if a player has an unassailable advantage. Finally, these results align with Gardner [39] who claimed that the perception of fairness of a game adjustment can be different depending on the circumstances.

Design consideration: Lowering the required skill level to play a game can lessen the difference in the players' performances. Therefore, I suggest that a lower score adjustment should be applied to games that require a lower skill level to avoid overbalancing the game and thereby increasing the chance of disengagement owing to the unacceptable competitive advantage given to the less skilled players.

4.4.2 The design of static game adjustments

The study results highlight two potential risks of the design of static game adjustments. These are adjustments that are made at the start and remain unchanged for the duration of the game. First, if the adjustment fails to balance the game (i.e. does not make enough difference to give the less skilled player a chance to win, or overbalances to give the less skilled player too much of an advantage) then the effect on engagement can be worse than when making no adjustment at all. This is what happened with the score adjustment in the digital table tennis game. Second, if players lose a sense of control as a result of the adjustment (e.g. playing with the non-dominant hand) and the game does not give the player the chance to take any decision or action to overcome this new challenge, the game can become frustrating, leading to disengagement. It is important to take these reflections into account when designing balancing adjustments to produce more engaging games.

4.4.3 Generalization of the results and limitations

This study shows the role that the level of skill required in a game has on the player engagement when balancing exertion games. I have provided evidence that game balancing should be different in games that require different skill levels to play. Since the focus is on the level of skills required in a game, the findings are applicable to other exertion games beyond those studied in the present work.

The findings of this study are also relevant to non-physical games. For example, the relation between players' skills needed to play a game, the score adjustment, and the non-acceptance of the competitive advantage could also be expected in other non-physical games. The disengagement owing to the unexpected physical challenges when limiting physical skills might be mainly relevant to physical games as physical skills are more a characteristic of physical than non-physical games. However, it is expected that in non-physical games there are other adjustments that can create unexpected challenges, leading the players to disengage.

For this research I studied a non-parallel game (i.e. a table tennis game) where each player's performance affects his or her opponent's performance. Although I chose a non-parallel game, the findings are relevant to parallel games because these findings do not depend much on the non-parallel aspect of the games. However, the study of game adjustments in parallel games is left for future work.

The study results have a number of limitations. First, I did not have much control over the internal mechanics of the digital game since I used the existing digital game Wii Sports Resort [103]. Therefore, I was not able to confirm whether it has an internal balancing method implemented. However, it appears it is very unlikely to have such a feature by observing how challenging it was for the more skilled participants to catch up in the score adjustment condition (see 4.3.1).

Second, I assessed participants' skills using a pre-questionnaire. As reported in 4.2.2, this was useful because it allowed us to pair the participants prior to the main experiment. Although this method of assessing participants' skills was enough for the purpose of this study, I acknowledge that I might have obtained a more accurate assessment of participants' skills by observing them playing before the main experiment.

Finally, the limited number of participants meant I could not perform an analysis of whether (and how) the motivation of the participants to practise physical activity influenced the engagement scores when playing with the proposed game adjustments. An analysis of how the findings would change according to the participants' motivations in playing table tennis would require more participants in order to prevent this analysis from having a low statistical power.

4.5 Conclusions

I reported results from a study where I measured and investigated player engagement after applying adjustments to a digital table tennis game and the traditional table tennis game in an attempt to balance the win probabilities of players with different skill levels. This work provides insight into player engagement when applying these adjustments.

The use of digital technology to play physical games can alter the level of skill required to play the game in comparison with the traditional game, for example when the digital game requires a lower skill level to perform a game action. I argue that when this happens, game balancing should be different. For example a six point adjustment in an eleven point game can be more suitable in the traditional table tennis game than in the digital one. When a lower level of skill is required to play a game, there can be a lower performance gap between players in the unadjusted game, which means a smaller adjustment is required to balance the game. The primary contribution here is insight into the role that the level of skill required in a game has on the player engagement when balancing exertion games. I identified two factors of disengagement and for each factor I proposed game design considerations.

I have explored two different possible game adjustments in exertion games. This work enhances our understanding of balancing exertion games. In the next chapter I report the results of a study where I investigated how altering sport equipment statically and dynamically can influence game balancing and player engagement using a digitally augmented table tennis game. One of the aims of next study is to design game adjustments that provide more control over the impact of these adjustments on players' performance and thus overcome one of the drawbacks found in this chapter 4.

Chapter V

Case study 2: Game balancing through altering sport equipment statically and dynamically

5.1 Introduction

In chapter 4 I studied the impact of score and performance adjustment in different game worlds. However, the game adjustments did not improve player engagement in either of the game worlds: digital table tennis and traditional table tennis. Another study was therefore needed in order to understand how to enhance player engagement through game balancing design.

A drawback of the adjustments I applied in the previous study (see chapter 4) is that I did not have much control over the impact of these adjustments on players' skills and players' performance. It was difficult to know beforehand the resulting players' skills when they play with the non-dominant hand, or whether (and how) a score adjustment would influence the players' play. Not knowing the impact of game adjustments on players' skills and players' performance has some risks, such as the decrease of player engagement because of players' loss of sense of control. For this reason, controlling the influence game adjustments have on players' performance is desirable. In particular, this control can be important in non-parallel games to moderate the influence of a player's actions over the other player's performance.

This chapter aims to address the game design challenge of enhancing player engagement in non-parallel games, and to fill the identified research gaps (see 2.4) by investigating whether altering different sport equipment, such as the bat or the table, supports game balancing and enhances player engagement. For the bat adjustment I altered the bat-head size, and for the table adjustment I altered the table size (playing surface area size). Altering the sport equipment was suitable for this study because it can be altered both statically and dynamically. A possible advantage of a dynamic adjustment over a static one is that it might help the players to adapt to the game adjustment better and control the impact of the game adjustment on the player's performance. To evaluate the advantages of a static versus a dynamic adjustment, I also evaluated the bat-head size and table size statically and dynamically. A static adjustment in a game describes an adjustment that is set at the start of the game and remains unchanged. A dynamic adjustment describes an adjustment that can be altered as the game proceeds.

I chose to alter the bat-head and table size because these adjustments could affect game balancing and player engagement better than the game adjustments studied in chapter 4. First, altering the bat-head size might alter the players' skills and performance in a more controllable way than asking them to play with the non-dominant hand. Moreover, dynamic adjustments might alter the game progressively, which can help players adapt to the game adjustment. This was not possible when I asked the players to play with the non-dominant hand. Second, altering the table size might provide game designers with more control over the players' performance than a score adjustment or performance adjustment that ask the skilled players to play with the non-dominant hand. Restricting players to different playing surface areas might alter their style of play, such as a more defensive play when the playing area is reduced close to the net.

The contributions of this study are the following:

- A set of game design strategies to facilitate engaging experiences when balancing physical games.
- Insight into how game adjustments, which alter sport equipment, affect the player experience and enhance player engagement in physical games.
- Insight into how game designers can moderate the influence of one player's performance on another's by facilitating a defensive play of the more skilled player through game adjustment design.
- Insight into how digital technology can be used as a design resource, such as for dynamically adjusting the sports equipment.

The research questions this study aims to address are the following: **How does game adjustment design that alters the sport equipment statically and dynamically affect game balancing and player engagement in non-parallel games?** To address this question, I defined the following sub-questions. Note that by "game adjustments" I mean the bat-head size, table size adjustments, and the no-adjustment condition.

- RQ1: Do different game adjustments impact game balancing differently?
- RQ2: Do different game adjustments impact game balancing differently depending on the frequency of the adjustment, i.e. static or dynamic?
- RQ3: Do different game adjustments impact player engagement differently?
- RQ4: Do different game adjustments impact player engagement differently depending on players' skill status, i.e. more skilled and the less skilled?
- RQ5: Do different game adjustments impact player engagement differently depending on the frequency of the adjustment, i.e. static and dynamic?
- RQ6: Is there an interaction effect among the different game adjustments, frequency of update and the difference in skill level of the players?

5.2 Methodology

In this section I focus on the aspects in which this study differs from the other case studies.

5.2.1 The game

For this study I chose a digitally augmented table tennis game. To augment the game I projected images onto the table surface to:

- Show the boundaries of the different table adjustments (table adjustment condition).
- Show an image of the bat each participant had to use at the beginning of each point (bat adjustment condition).
- Show the location of where the ball hit the table, show the participants' score after each point played, and indicate the participant that is serving (table and bat adjustments).

5.2.2 Study design

The study was a 3x2x2 split-plot design [55, p. 54]. I defined the game adjustment as a within factor with three levels: no-adjustment (regular table tennis game), and bat and table adjustments. The order of the game adjustments was counterbalanced to avoid any order effect.

I defined the frequency update as a between factor with two levels: static and dynamic. Each pair of participants was randomly assigned to one of these two frequency updates. Therefore, each pair of participants played with the table and bat adjustments, but only in the static or dynamic frequency update.

Finally, I defined players' skill status as a between factor with two levels. As I matched participants with different skill levels, in every match one participant was assigned as "the more skilled player of the match", and the other as "the less skilled player of the match".

I chose a split-plot design because I wanted to limit the number of conditions per participant to reduce the impact of participant fatigue on the results. I defined as a within factor the game adjustment, which allowed me to explore the differences in playing with the table adjustment, bat adjustment and no-adjustment during the semi-structured interviews.

5.2.3 Participants

I selected participants that had previously played the traditional table tennis game. I recruited 42 participants: 16 females and 26 males with an average age of M=26.1 years and SD=10.1. Twenty-two of these participants played in the static frequency update condition and the other 20 in the dynamic frequency update condition. The participants' self-reported table tennis skill levels in the pre-questionnaire were novice (2 participants), beginner (17), competent (11), proficient (12) and expert (0).

I used the information from the pre-questionnaire to pair the participants. The objective was to create pairs of participants with as large as possible a difference in skill level between the participants in each pair. The pairings were as follows: competent vs. proficient (2 pairs), beginner vs. competent (8), beginner vs. proficient (9), novice vs. proficient (1) and novice vs. competent (1). Once all participants were matched, I randomly assigned each pair of participants to play the game with the static frequency update or the dynamic frequency update.

As I required self-assessment of participants' skills, there was a possibility of creating pairs of participants whose skills were actually quite similar. Therefore, as explained in 3.2, I decided to discard the pairs whose participants' skill level difference was significantly smaller than that of the other pairs in order to prevent evaluating pairs whose participants were too similar in skill. I checked the results of the final score difference between the participants of each pair in the no-adjustment condition, and I looked for outliers. As I did not find any, I concluded there was a satisfactory difference between participants' skills in all pairs, and therefore I did not discard any pair.

5.2.4 Game adjustment design

The game adjustments were based on altering the bat-head size or the table size (playing surface area). In the bat and table dynamic adjustments, I adjusted the difficulty level after each game point according to the difference in score between the participants. I believed this would provide a greater challenge and keep the game outcome more uncertain, which is important for player engagement (see 1.3). The more advantaged a participant was in the score, the harder the challenges this participant had to face: playing with a smaller bat-head or a smaller table. In contrast, in the bat or table static adjustment, the game was only altered before the first game point. I handicapped the more skilled participant by asking him or her to play with a smaller bat-head or a smaller table of a fixed size for the whole match.

I decided that the table or bat adjustment of the static frequency update would correspond to the adjustment in the dynamic frequency update when the score difference was 11 points: a bat head-size of 25% of the size of the regular head size, and a table size of 30% of the size of the regular table tennis table (see the table adjustment design in 5.2.4 and bat adjustment design in 5.2.4). Eleven points is the rounded average of all possible score advantages in a 21 point game and so it is most representative of the possible differences in skill levels between the participants.

To associate game difficulty levels [1-"very easy", 5-"very hard"] with different bat-head and table sizes, and to define a mapping between players' score differences and game difficulty levels, I conducted two pre-experimental studies. This allowed me to design the table and bat adjustments in both static and dynamic frequency updates.

Table adjustment design

To adjust the table size I did not physically alter the table: I used digital technology to make the participants' experience as if they were playing with a smaller table (see Figure 5.1). I mounted a projector on the ceiling facing down towards the physical table tennis table. This projector displayed a different table tennis table on top of the physical table. To alter the table sizes, I first calculated the virtual coordinates of the regular table and based on these I calculated the virtual coordinates of the other table sizes.

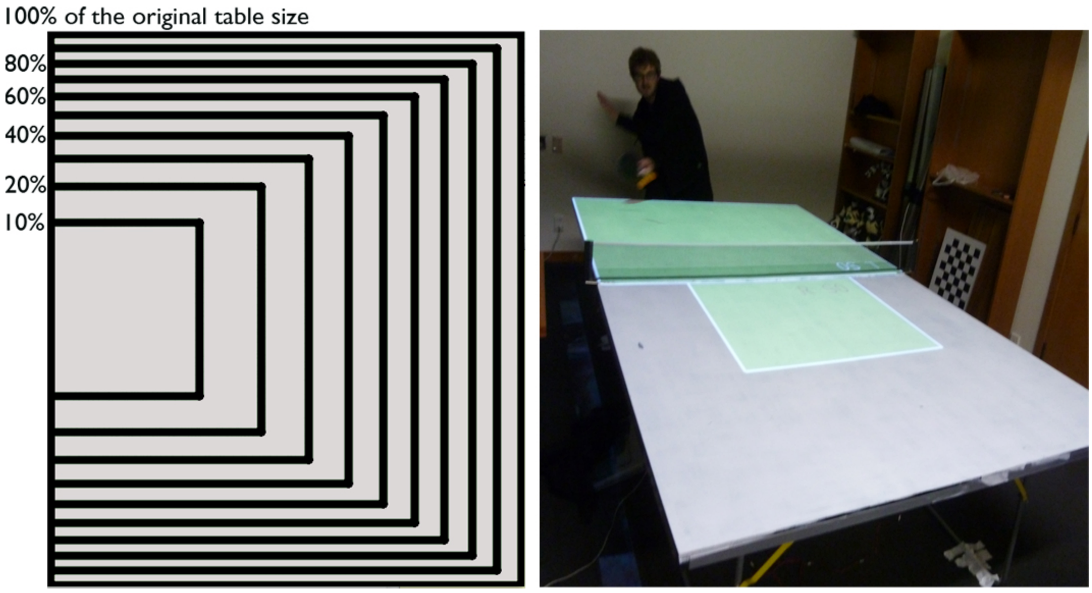

Figure 5.1: Case study 2. Table adjustment design. On the left the different table sizes (the net is on the left side). The shrinkage of the table is towards the centre of the net and all table adjustments have the same aspect ratio. On the right a participant playing with a table adjustment

I conducted a pre-experimental study with 8 participants to evaluate the experience of playing with smaller table sizes. I observed that shrinking the area of the table towards the center of the net changed the disadvantaged participants' style of play towards a more defensive style. Since this helped the opponent to return the ball, I decided the game adjustment should shrink the table towards the centre of the net.

I evaluated the perception of difficulty [1-"very easy", 5-"very hard"] of these eight participants playing with different table sizes [regular table size, 10% of its original size] (see Figure 5.1). This informed the relationship between table sizes and difficulty levels (see Figure 5.2).

In the dynamic adjustment condition I used a linear mapping to map the range of

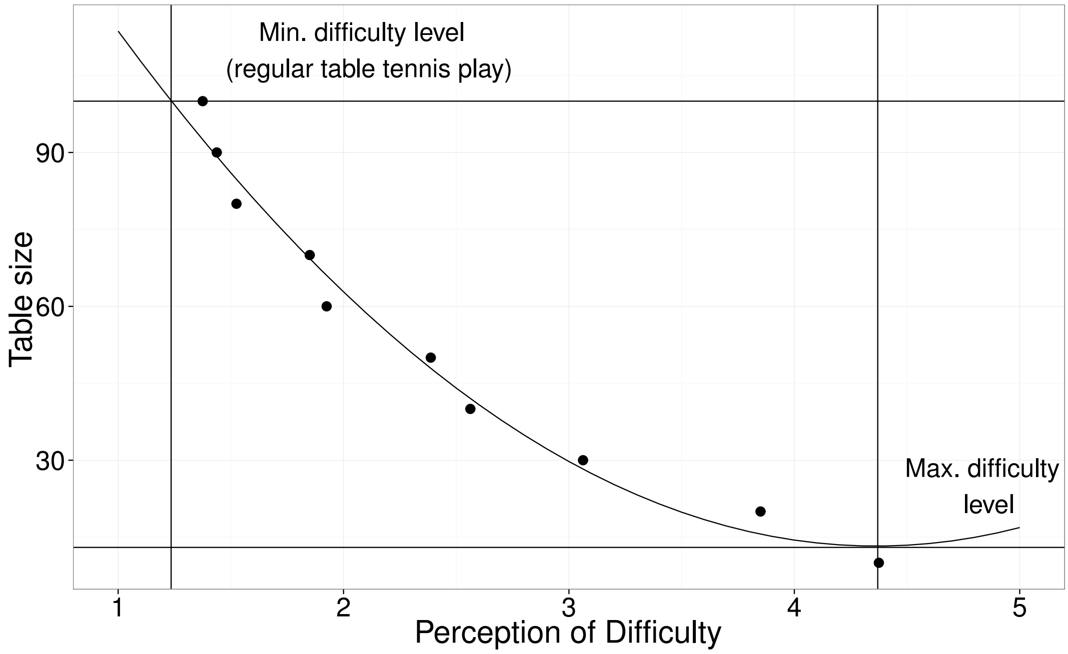

Figure 5.2: Case study 2. Pre-experimental study of table adjustment design. Perception of difficulty of playing with different table sizes (percentage size of table compared to full size). Black dots represent the data collected from the pre-experimental study. A polynomial of degree two is fitted to the data

differences in score [0,20] to a range of difficulty levels. The range of difficulty levels was based on the difficulty levels of playing with the different table sizes [regular table size, 10% of its original size]. A difference in score of zero was associated with the level of difficulty of no-adjustment (minimum difficulty level defined for the game), and a difference in score of 20 points to the level of difficulty associated at the hardest adjustment (10% of the table size). Then I used the polynomial mapping obtained from the pre-experimental study to map the perception of difficulty to the different table sizes, see Figure 5.3. I implemented software that calculated the game difficulty level to be set after each game point, and that updated the size of the virtual projected table using the results of the pre-experimental study (Figure 5.2).

Bat adjustment design

For the bat adjustment I altered the head size of the bat and kept the handle unchanged (see Figure 5.4). I used three bat adjustments: regular bat, a bat with a head 50% of the size of the original head, and a bat with a head 25% of the size of the original head. I

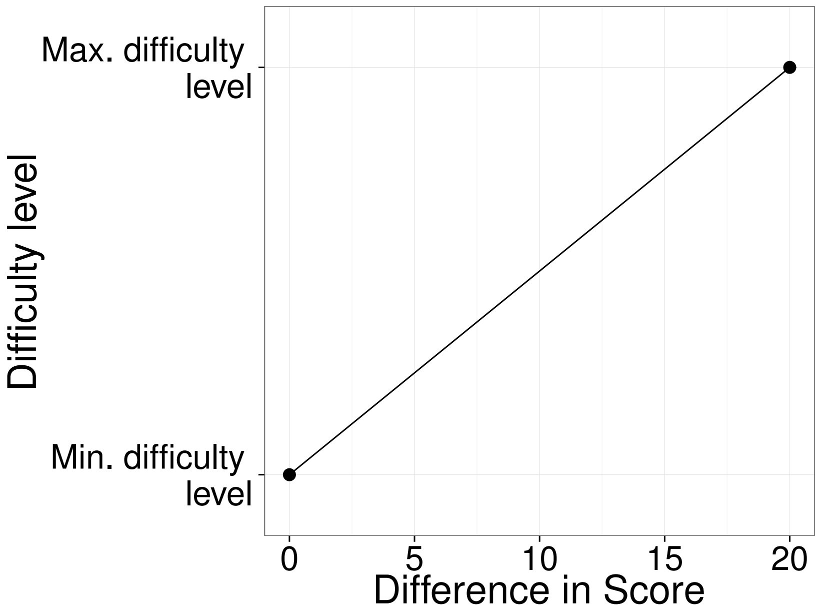

Figure 5.3: Case study 2. Adjustment design. Difference in score and the difficulty level associated.

felt that using three head sizes was sufficient for investigating the player experience with different head sizes. I could not implement a change of head size using digital technology at this time, but this might be possible in the future. For now, I used three different head sizes to simulate this future possibility of changing the head size, and used digital technology to project on the physical table the bat each player had to use after each game point for three seconds.

I followed the same procedure as with the table adjustment design: I conducted a pre-experimental study (in this case with 9 participants) to associate different difficulty levels with playing with different bat-head sizes (see Figure 5.5). For the bat adjustment design, I defined the values of the minimum difficulty level and maximum difficulty level to be the same as in the table adjustment design (same position of the vertical bars in Figure 5.2 and 5.5), because this would allow for a more fair comparison between the bat and table adjustments. However, for the bat adjustment design there was the limitation of the limited number of bat-head sizes. Therefore, for each difference in score between the players, I could not always provide the bat with the right head size (the head size determined by the pre-experimental study, Figure 5.5). Instead, I asked the players to play with the bat whose head size was the closest to the right head size. Therefore, the bat did not necessarily change after each game point.

Figure 5.4: Case study 2. Bat adjustment design. Regular table tennis bat (left), 50% head size (middle), 25% head size (right)

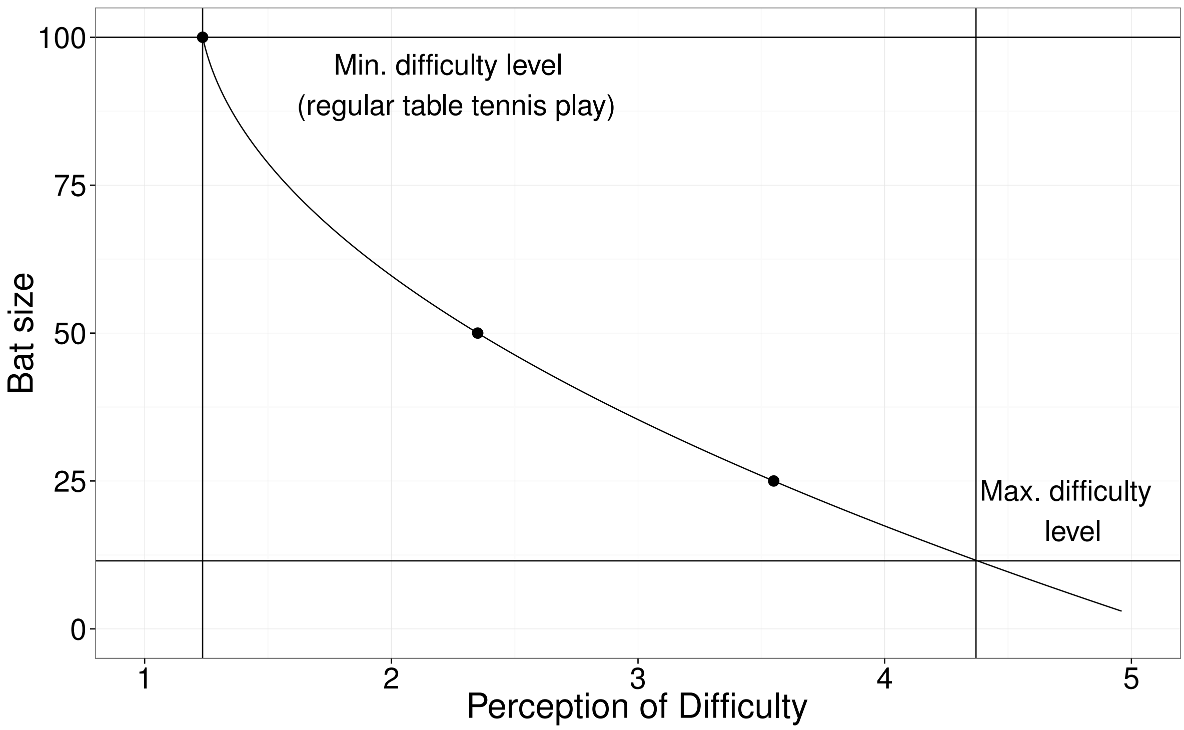

Figure 5.5: Case study 2. Pre-experimental study of bat adjustment design. Participants' perception of difficulty of different head sizes (percentage head-size compared to full head-size). A polynomial of degree two fitted the data

5.2.5 *Material and setup of the study*

I used the equipment and technological development described in 3.4.

5.2.6 *Procedure*

The participants warmed up for 6 minutes playing table tennis in the three game adjustments (2 minutes each). Before starting the games, I requested that the participants play competitively in the study. They then played 21-point games in each of the game adjustments. I opted for a 21-point game instead of an 11-point game to allow sufficient time for the participants to experience each game adjustment. After each game, the participants completed a questionnaire to assess their engagement. Finally, the participants were interviewed in pairs using a semi-structured interview.

5.2.7 *Data collection and analysis methods*

I measured participants' difference in score through repeated measures ANOVA (after validating its assumptions) with game adjustments as a within-subjects factor and the frequency update as a between-subjects factor. I used post-hoc with Bonferroni correction for the pair-wise comparison. I also collected the win/lose ratio and used the Fisher's exact test to evaluate whether there was a relationship between the number of matches won by the more skilled participants and the frequency of update (of the table and bat adjustments), and whether there was a relationship between the number of matches won by the more skilled participants and the table and bat adjustments.

To collect information about the experiences of the participants I used the engagement scale questionnaire (five-point scale) from the O'Brien model of engagement [74] (see 3.3.1). The questionnaire used is in Appendix B.This is the same engagement questionnaire used in the prior study reported in chapter 4. The player engagement scale in this study had high reliability (Cronbach's-α= 0.83).

The engagement scores were analysed using a multilevel model (MLM) for mixed-design [36, p. 617]. I defined the engagement score as the outcome variable and added to this model the following predictors in this order: game adjustments, frequency update, players' skill status and the different interaction effects among these variables. This model informed us which predictors contributed significantly to the engagement scores and I used the results to answer the research questions from R1 to R4. I note that the model can provide more information than required for answering the research questions, such as the main effects of the frequency of update. However I report just those results that helped me to answer the research questions.

A MLM was used instead of the traditional ANOVA test because it has the ability to better handle missing data [36, p. 860]. I used an online tool for the engagement questionnaire. I could not retrieve the data of three participants in one of the three game adjustments they played because the system failed to save the data correctly for these cases. As I wanted to keep the data of these participants, the MLM was more suitable. For the MLM I used post-hoc with Bonferroni correction to compare between game adjustments.

For both repeated measures ANOVA (analysis of the participants' difference in score) and MLM (analysis of the participants' engagement scores), I performed the appropriate tests to validate its assumptions. The significance level was set at α=0.05.

Finally, I used semi-structured interviews to assess which game adjustments participants preferred, and to evaluate the different reasons for their preferences, to better understand the reasons why different game adjustments provided different levels of engagement.

5.3 *Results*

5.3.1 Game balancing

RQ1: Do different game adjustments impact game balancing differently? The table and bat adjustments significantly reduced the score differences (in absolute values) compared to the no-adjustment condition (see Figure 5.6). A repeated measures ANOVA on the score difference between participants revealed differences between game adjustments (bat, table and no-adjustment), $F(2, 40) = 20.72, p < .001, \eta_G^2 = 0.32$. Pairwise comparisons with Bonferroni correction showed that the no-adjustment score differential (M=14.2, SD=5.1) was greater than the table adjustment (M=7.6, SD=4.2) with $p < .001$, and the bat adjustment (M=8.3, SD=4.7) with $p < .001$. No significant differences were found between the score differential of the table adjustment and bat adjustment ($p = 1.0$).

Figure 5.6 shows that in the no-adjustment the more skilled participants won all games. In contrast, the win/lose ratio was more balanced in the table and bat adjustments. Taking into account both static and dynamic frequency of updates (I differentiate between the the static and dynamic frequency of updates in RQ2), in the bat adjustment, the more skilled participants won 77% of the matches (17/22). In the table adjustment, the more skilled participants won 68% of the matches (15/22). The Fisher's exact test reported no significant relationship between the number of matches won by the more skilled participants and the table and bat adjustments ($p = .73$).

To summarise, the table and bat adjustments reduced the score difference between the participants and balanced the win/lose ratio compared to the no-adjustment condition. However, no differences were found between the table and bat adjustments.

RQ2: Do different game adjustments impact game balancing differently depending on the frequency of the adjustment, i.e. static and dynamic? Regarding the difference in score, I did not find significant differences between the participants grouped in the static frequency update and those in the dynamic frequency update, $F(1, 20) = 0.94, p = 0.34, \eta^2_G = 0.03$. However, the frequency of update had an impact on the win/lose ratio of the game adjustments.

Figure 5.6 shows that in the dynamic frequency updates of the table and bat adjustments, the more skilled participants won all games. However, the more skilled participants won 55% of the matches (6/11) in the static bat adjustment, and 36% of the matches (4/11) in the table static adjustment. The Fisher's exact test indicated a significant relationship between the number of matches won by the more skilled participants and the frequency of update of the adjustment ($p < .01$).

To summarise, regarding the final score difference there were no significant differences between the participants grouped in the static frequency update and those in the dynamic frequency update. However, the more skilled participants significantly won more matches when they played in the dynamic frequency of update than in the static frequency of update.

5.3.2 Player engagement

RQ3: Do different game adjustments impact player engagement differently? The game adjustments did impact differently on player engagement. There were significant differences among the no-adjustment (M=3.50, SD=0.47), table adjustment (M=3.80, SD=0.37) and bat adjustment (M=3.69, SD=0.41) conditions, $\chi^2(2) = 16.41, p < .001$ (see Figure 5.7).

The post-hocs with Bonferroni corrections showed that participants were significantly more engaged playing with the table adjustment than without any adjustment ($p < .01$).

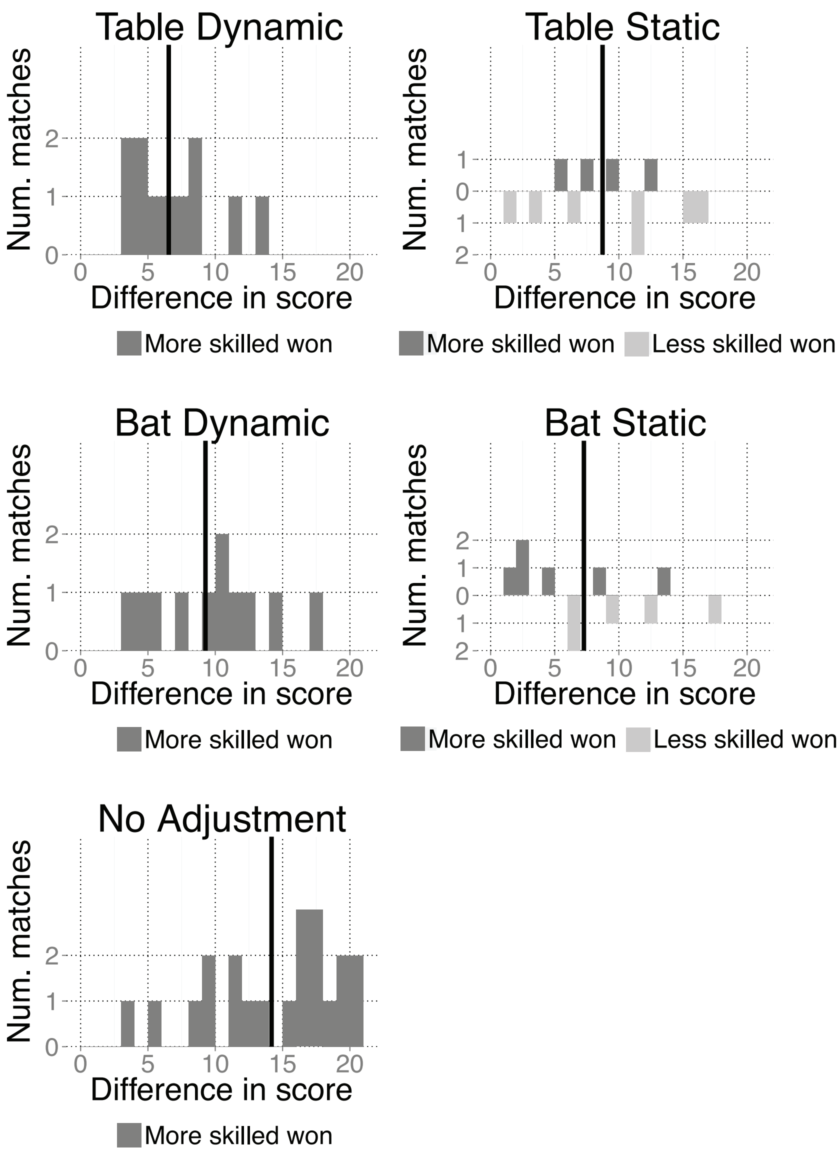

Figure 5.6: Case study 2. Difference in score, in absolute values, of the game adjustments with the different frequency updates. The wins of the more skilled participants and the less skilled participants are shown. Vertical line represents the mean of the difference in score

Similarly, they were significantly more engaged playing with the bat adjustment than without any adjustment ($p = .02$). I did not find significant differences in the participants' engagement scores between the table and bat adjustments ($p = .37$).

Most of the participants reported in the interviews that the no-adjustment condition provided a less engaging experience than the table or bat adjustments, mainly because of

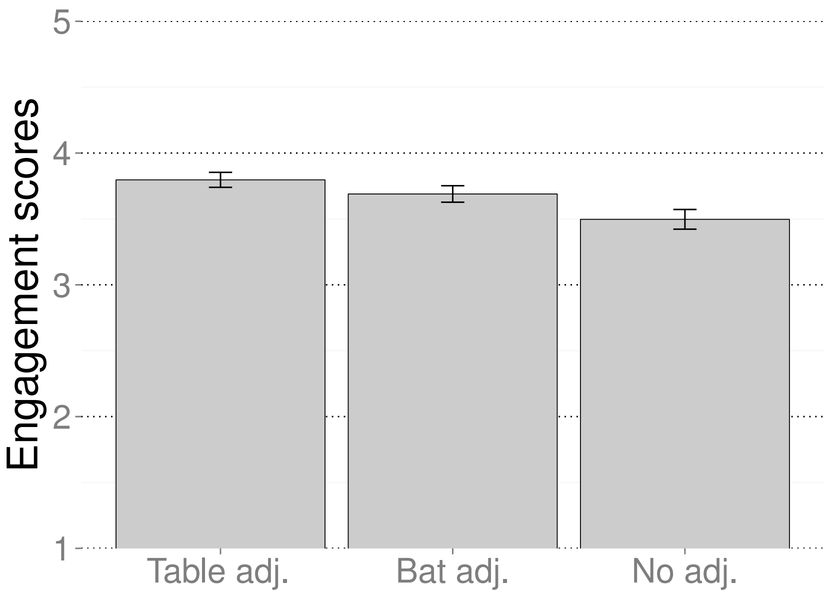

Figure 5.7: Case study 2. Mean and standard error bars of the engagement scores of the table adjustment, bat adjustment and no-adjustment conditions

participants' skill differences and the resulting gameplay this caused. For example, one participant explained that the no-adjustment condition was not enjoyable because he had to spend most of the time picking up the ball from the floor because of the difficulties in countering the attacks of his opponent.

The most frequently reported reasons for the increase of engagement in the table or bat adjustment were the increase of the challenge (e.g. saying "*can I get it in the small space constantly?*"), the creation of new goals (e.g. saying "*I enjoyed the bat adjustment more because I could get better*") , and players' score, such as the ability of the less skilled participants to score points and thus play a closer match.

RQ4: Do different game adjustments impact player engagement differently depending on players' skill status? There were no significant interaction effects between game adjustments and players' skill status, $\chi^2(2) = 0.34, p = .844$. However, I found a significant higher-order interaction effect (see RQ6 below).

RQ5: Do different game adjustments impact player engagement differently depending on the frequency of the adjustment? There was a significant interaction effect between game adjustments and the frequency updates $\chi^2(2) = 6.44, p = .039$. Since I found higher-order significant interactions involving game adjustments and frequency updates (see RQ6 below), I did not investigate this research question further. Higher-order interactions supersede the lower-order interactions [36].

RQ6: Is there an interaction effect among the different game adjustments, frequency of update and the difference in skill level of the players? The difference in engagement scores between the dynamic and static frequency updates was greater for the more skilled participants than the less skilled participants in the table and bat adjustments (see Figure 5.8). Moreover, in the static frequency update condition there did not seem to be any difference in the engagement scores among game adjustments for either the more skilled participants or the less skilled participants. However, in the dynamic frequency update condition, the engagement score differences between the table and bat adjustment conditions compared to the no-adjustment condition were greater for the more skilled than the less skilled participants. That is why there was a significant interaction effect between game adjustments, the frequency of updates (static and dynamic) and players' skill status, $\chi^2(2) = 8.36, p = .015$.

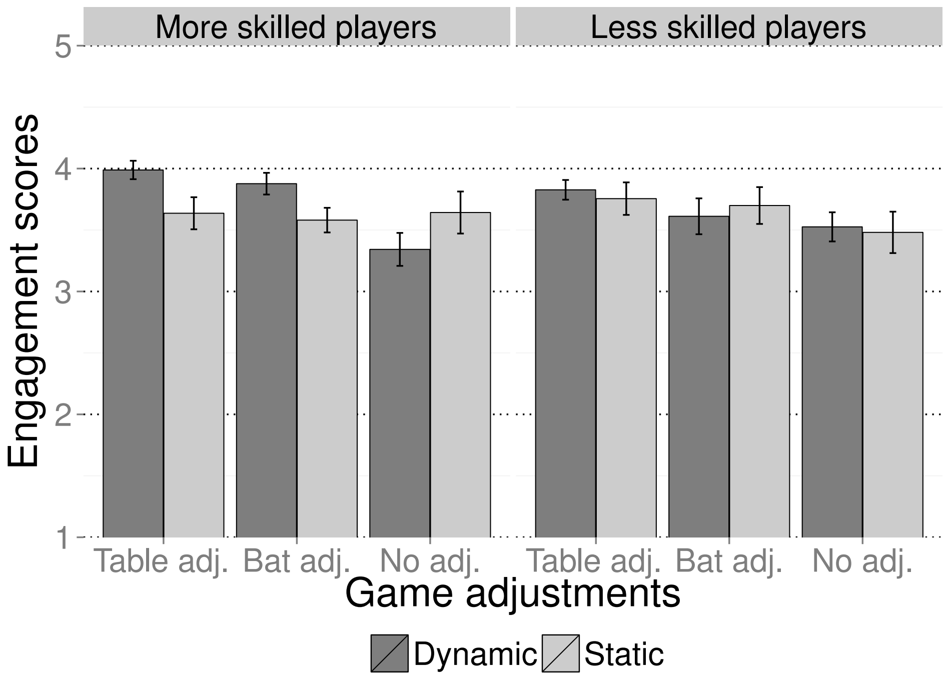

Figure 5.8: Case study 2. Mean and standard error bars of the engagement scores of the table adjustment, bat adjustment and no-adjustment of the more skilled and less skilled participants playing in the dynamic and static frequency updates

To make the three-way interaction clearer I conducted a planned contrast analysis to compare the conditions shown in Figure 5.9.

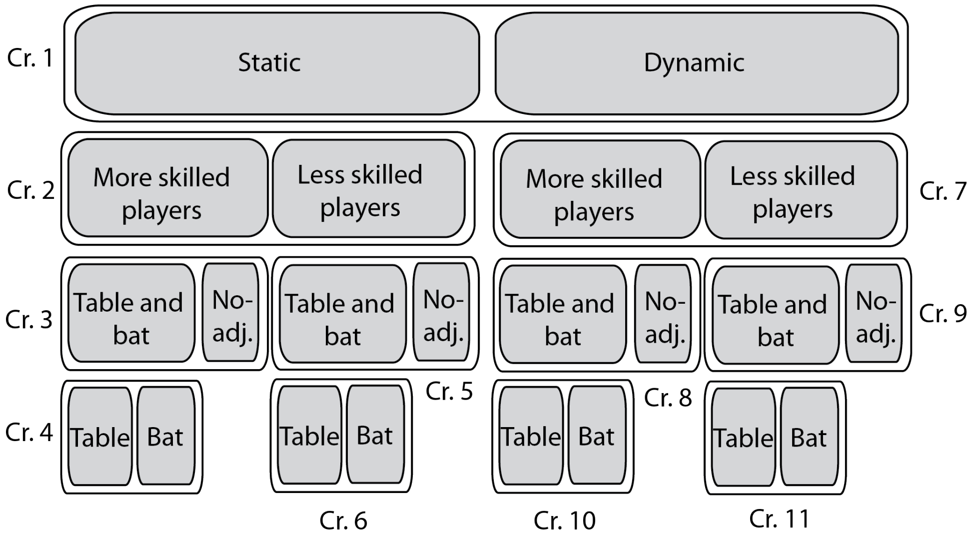

Figure 5.9: Case study 2. Planned contrast analysis of engagement scores. For example, Cr. 1 (Contrast 1) compares engagement scores between static and dynamic frequency updates; Cr. 2 compares the engagement scores between the more skilled participants and less skilled participants, who played in the static frequency update; and Cr. 3 compares the engagement scores between the table and bat adjustment to the no-adjustment for the more skilled participants who played in the static frequency update

The results of this planned contrast analysis align with my first analysis of the interaction effects in **RQ6**, where I stated:

- "*In the static frequency update condition there did not seem to be any difference in the engagement scores among game adjustments for either the more skilled participants or the less skilled participants*". For the more skilled participants there were no significant differences between the table and bat adjustments, compared to the no-adjustment condition (Cr. 3: $b = -0.01, t(73) = -0.26, p = .80, r = .03$), and no significant differences between the table and the bat adjustments (Cr. 4: $b = -0.03, t(73) = -0.43, p = .67, r = .05$). For the less skilled participants, there was a significant difference between the table and bat adjustments, compared to the no-adjustment condition (Cr. 5: $b = 0.08, t(73) = 2.03, p = .046, r = .23$), but no significant differences between the table and bat adjustments (Cr. 6: $b = -0.03, t(73) = -0.43, p = .67, r = .05$).

- "*In the dynamic frequency update condition, the engagement score differences between the table and bat adjustments compared to the no-adjustment condition are greater for the more skilled than the less skilled participants*". For the more skilled participants there was a significant difference between the table and bat adjustments, compared to the no-adjustment condition (Cr. 8: $b = 0.20, t(73) = 4.48, p < .01, r = .46$), but no significant differences between the table and bat adjustments (Cr. 10: $b = 0.06, t(73) = 0.81, p = .42, r = .09$). For the less skilled participants there were no significant differences between the table and bat adjustments, compared to the no-adjustment condition (Cr. 9: $b = 0.06, t(73) = 1.55, p = .13, r = .18$), and no significant differences between the table and the bat adjustments (Cr. 11: $b = -0.1, t(73) = -1.57, p = .12, r = .18$).

The results of the engagement scores (Figure 5.8) were in line with the participants' preferred game adjustments as reported in the semi-structured interviews (Figure 5.10). In the interviews I asked the participants which game adjustment they preferred or whether they did not have any preference. The more skilled participants in the dynamic frequency update condition preferred playing with an adjustment, in particular the table adjustment, and the least preferred was the no-adjustment condition. Moreover, for the more skilled participants who played in the static frequency update condition, there was not any game adjustment that was significantly more preferred than the others (see Figure 5.10). For the less skilled participants, the game adjustments selected as more preferred did not seem to change depending on the frequency of update of the adjustment. In addition, the less skilled participants tended to prefer the table adjustment to the bat and no-adjustment conditions.

From the qualitative analysis I identified different factors that contributed to altering player engagement: the sense of control and variety of gameplay, the training of strokes, the sense of achievement and the style of play.

Sense of control and variety of gameplay

The more skilled participants explained how the table and bat adjustments altered their performance and how this influenced their engagement. Playing with a smaller bat-head size decreased their sense of control, which influenced player engagement. Fifty-five % of the more skilled participants playing with the static bat adjustment and 36% of those playing with the dynamic bat adjustment reported that it was hard to hit accurately,

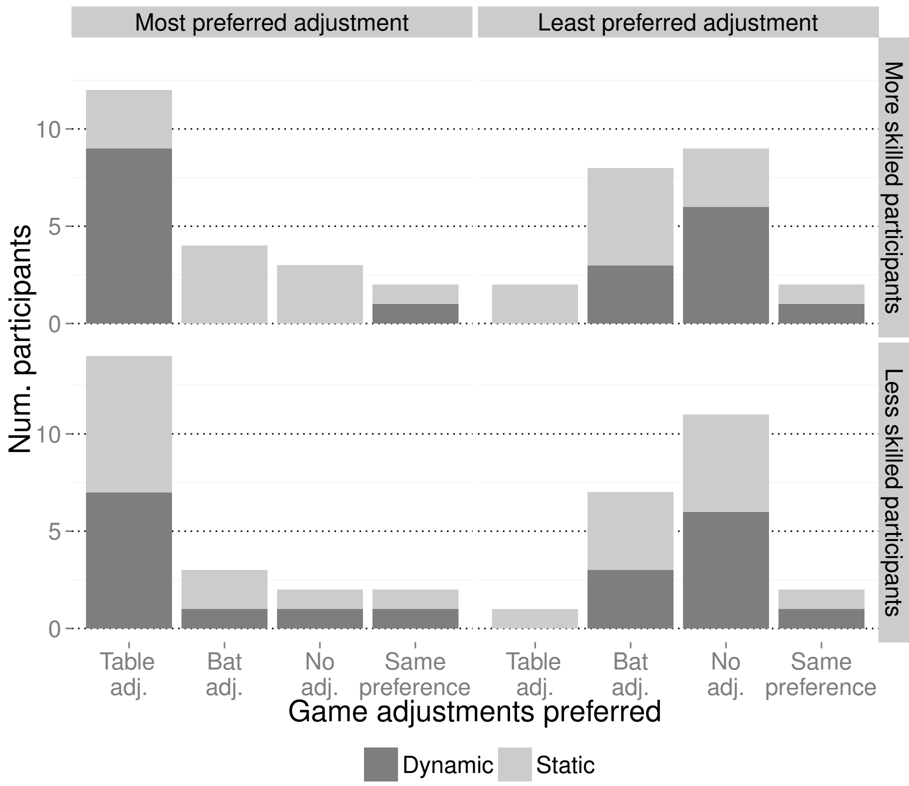

Figure 5.10: Case study 2. Participants' preferences in each of the game adjustments. The most preferred game adjustment and the least preferred game adjustment are shown

which decreased their sense of control and thus increased the number of mistakes. This decreased player engagement, e.g. saying "*playing with a small bat was quite challenging (...) I did not enjoy it as much as in the table (...) I could not hit the ball how I wanted*". This also influenced the opponent participant as well. Interviewer: "*How did the different game conditions influence your enjoyment?*". A participant: "*For the bat adjustment, the number of mistakes and seeing the other participant do things he would not normally do*". Playing with a smaller bat-head size also decreased participants' interest in the game because of the limitations on the variety of strokes, such as top or back spin, e.g. saying "*the small bat was interesting, but only interesting over a short period (...) In the first half an hour you probably exhausted what you can do*".

In the table adjustment, 45% of the more skilled participants playing in the static frequency update also stated that the game restricted the variety of strokes they could perform. In contrast, only 20% of the more skilled participants in the dynamic frequency update reported the same. This suggests that the dynamic frequency update can help in providing more variety of gameplay and a greater sense of control than the static frequency update.

Training

The more skilled participants also reported that when the game adjustment prevented the practice of useful table tennis skills, their engagement decreased. One participant found the table adjustment more worthwhile than the bat adjustment because with the regular bat they could practise and think about their skills. On the other hand, another participant commented that a downside of the table adjustment was that since the table shrank towards the centre of the net, this prevented table tennis strokes that bounce close to the edge from being played. This participant stated that these strokes are usually the ones players look for when playing normal table tennis. Regarding the bat adjustment, another participant pointed out that using a different bat-head size could generate concerns for acquiring "bad habits" and it could limit the transfer of skills to a regular table tennis game.

Sense of achievement

The participants took the limitations imposed by the explicit table and bat adjustments as opportunities to create new goals, which helped to enhance their sense of achievement and make the game more rewarding. This happened especially in the dynamic table adjustment because of the explicitness of the adjustment and the frequent and clear feedback of the table changes. Participants could reduce the table size every time they increased their advantage in the score. Interviewer: "*Tell me something you remember you found enjoyable?*". Participant: "*When the table got smaller whenever I kept scoring, it was like a goal to keep going*".

Style of play

Finally, I observed that the table and bat adjustments altered the style of play of the more skilled participants towards a more defensive style of play. My observations were in line with participants' reports. Seventy per cent of the more skilled participants playing in the bat and table adjustment conditions stated that playing with the bat or table adjustment made them play more defensively. This change of style of play helped the less skilled participants counter their opponents' strokes, e.g. saying "*the ball was coming nicer for me*".

5.3.3 Summary

The studied table and bat adjustments helped reduce the difference in score between participants compared to the no-adjustment condition. While the more skilled participants won all matches when the game was played in the dynamic frequency update, the win/lose ratio for the more skilled participants was more balanced when the game was played in the static frequency update.

Playing with either the table or bat adjustments helped to enhance player engagement because it provided a more suitable level of challenge than the no-adjustment condition. However, the analysis showed the engagement scores varied depending on players' skill status and the frequency of update.

For the more skilled participants, the dynamic frequency update was more engaging than the static one, and the table adjustment preferable to the bat adjustment. Playing with the dynamic frequency update provided a higher sense of control and a greater variety of shots to be practised than the static frequency update. Moreover, with the dynamic frequency update, participants could set more goals and this helped to enhance the sense of achievement. The explicitness and frequency of update of the dynamic table adjustment enhanced the sense of achievement and made the game more rewarding than the dynamic bat adjustment.

Finally, the table and bat adjustments helped the less skilled participants to counter the attacks of the more skilled participants because of the change of style of play of the more skilled participants towards a more defensive style of play.

5.4 Discussion

This study shows how game adjustment design that alters the table tennis sport equipment statically and dynamically affects game balancing and player engagement. The game adjustments studied effectively created a more balanced game and enhanced player engagement for players with different skill levels. Regarding game balancing, this study also shows the differences between dynamic and static adjustments. For example, dynamic adjustments rewarded the more skilled players by encouraging wins. A similar finding was found in Bateman et al. study [12]. Rewarding the skilled players can be important for game balancing [1, p. 324].

I found dynamic adjustments enhanced player engagement more than static adjustments as they allowed participants to adapt to the game better, and helped in providing new goals and in enhancing the sense of achievement for players. This helped in countering the downside of limiting the players' skills and the performances (e.g. variety of strokes that could be applied). In the following section I describe a set of game design strategies that reflect the lessons learned in this study about how one could enhance player engagement.

5.4.1 Game design strategies

The strategies below are not an exhaustive list but rather a starting point to understand how to facilitate engaging experiences. Also, I note the limitations of the present game design strategies because they were derived from one experiment with one physical game. However, they can be used as inspirational strategies for future game balancing designs and for encouraging a future investigation into how they could be generalised to other types of games.

Goal 1: How can we make an engaging game adjustment that limits players' skills?

I formulated this goal inspired by how the table and bat adjustments limited the participants' skills, such as the variety of shots that could be applied, and reduced the sense of control (see 5.3.2), while still being able to enhance player engagement.

Context: Game designers have two approaches to balance a game: help the weaker player (e.g. [12]) or disadvantage the stronger player (e.g. case study in chapter 4). In a digital game, where game designers have control over the virtual environment, both approaches can be relatively easy to implement. However, in a non-digital game it can be difficult to enhance a player's performance, even though disadvantaging the stronger players might be disengaging (case study in chapter 4). How can we design these game adjustments to be more engaging?

Strategy 1: Support the training of useful sport skills

A first solution is to encourage players to train in useful sport skills that can be applied in a regular game. This can enhance player engagement not for the pleasure of playing with the game adjustment, but for the rewards that are external to this play (extrinsic motivation) [96]. I derived this strategy inspired by participants' reports of their experience (see 5.3.2). Participants found the table adjustment more worthwhile than the bat adjustment as they could practise their table tennis skills more. However, another participant also reported feelings of frustration in the table adjustment because he was not permitted to place the ball in the corners of the regular table as he would normally do in a standard game. This can align with the Technology Acceptance Model (TAM) theory [31], which argues the perception of "usefulness" as a key motivation factor to use a technical system. In the context of games, players might relate the concept of "usefulness" to the training of useful sport skills.

Strategy 2: Provide opportunities for setting new short-term goals

A second strategy is to offer the players new short-term game goals to enhance players' intrinsic motivation [96]. Participants reported feeling more engaged by the new goals the game adjustments offered to them. This happened especially in the dynamic table adjustment, where participants reported feeling motivated to score to reduce the table size as much as possible (see 5.3.2). The challenges the players face are important for games and sports [47] [51] [56], so game adjustments that facilitate new goals to players should be encouraged to enhance player engagement. Prior work also identified the importance of providing short-term goals [24] [78]. Vorderer et al. [98] argue that the success in a competition can increase the motivation to continue playing to face the next competitive challenge. This is another reason why short-term goals should be facilitated because they can enhance the players' motivation for playing.

Strategy 3: Provide dynamic gameplay

Another strategy is to implement a dynamic adjustment to facilitate dynamic gameplay. Game adjustments that facilitate dynamic gameplay are those adjustments that can alter the player's actions and the level of challenge dynamically. Different ways of altering the player's actions can be useful to progressively control the influence of one player's actions on the other's performance. In addition, altering the level of challenge progressively can help the players to adapt to the game adjustment better. An example of dynamic gameplay is the dynamic table adjustment of the study reported in this chapter. In this condition, the more advantage a player had in the score, the more defensively this player had to play, which helped in mediating the influence this player had on his or her opponent. This progressive adjustment also helped the players to adapt to the game adjustments better and provide a greater sense of control than the static adjustments (see 5.3.2).

Goal 2: How can we make an explicit game adjustment engaging?

I formulated this goal inspired by the results of this study that showed that explicit game adjustments can be used as an ingredient to enhance player engagement (see 5.3.2). By contrast, prior work showed that explicit adjustments can also have a negative effect on players [11] and be less desirable than implicit adjustments [25] [41].

Context: A game designer might need to apply game adjustments for balancing a game that are difficult to hide. So, how we can use the explicitness of an adjustment to design engaging experiences?

Strategy: Enhance the sense of achievement

Explicit adjustments for game balancing should be used as an opportunity to enhance player engagement. One way I found the awareness of an adjustment could help in enhancing player engagement is through increasing their the sense of achievement. In the dynamic table adjustment, players were motivated to keep scoring to reduce the table size as much as possible (see 5.3.2). This strategy can be aligned with the second strategy of goal 1, because one way to enhance the sense of achievement is to provide opportunities for setting new short-term goals.

Prior work already identified the importance of providing a sense of achievement to players, as well as the rewards and punishments given to them. This could be useful for designing dynamic explicit game adjustments in order to understand how to provide new goals, disadvantage players, reward players and provide feedback about player advancement. It has been suggested that the success of "World of Warcraft" came from the way in which advancement and rewards are distributed, which maximises players' commitment [35].

Goal 3: How can we design an engaging game adjustment for balancing non-parallel games?

I formulated this goal inspired first by the results of how the difference in skill level between participants impacted the gameplay of the table tennis game in the no-adjustment condition (see the answer to R3 in 5.3.2). And second, by how the studied game adjustments helped moderate the influence of a participant's actions over the opponent's performance (see 5.3.2).

Context: This goal focuses on the design of game balancing in non-parallel games, where a player's actions affect his or her opponent's performance. A large difference in skill level between players in non-parallel games can impact the gameplay and reduce the players' interest and engagement in the game. How can we design game adjustments for balancing non-parallel games that moderate the influence of one player over the other player?

Strategy: Assist the less skilled players by altering the style of play of the more skilled players

One solution is to change the style of play of the more skilled players. For example, in the table tennis game studied, the table adjustment induced a defensive play, which helped the less skilled participants to return the ball to the opponents' table more easily (see 5.3.2).

5.4.2 Generalization of the results and limitations

I acknowledge that the game design strategies proposed are not an exhaustive list. However, the proposed strategies can be useful to help balance physical games and build on prior design strategies (e.g. [41], [70]) by focusing on specific aspects of balancing such as making an explicit adjustment engaging, or balancing non-parallel games. In addition, the proposed strategies extend the ones already used in sports given the opportunities digital technology to enhance and dynamically alter the game.

The study results are not just applicable to table tennis. The game design strategies proposed can have implications for a wide range of physical games because they focus on game design goals and strategies that are not specific to table tennis. The game adjustment designs can straightforwardly be applied in some games (e.g. tennis, badminton), though less easily in others (e.g. basketball). For example, in squash we could limit the squash court and alter the style of play of the skilled players as we did in the table tennis in this study. Despite this limitation, the contribution of this work goes beyond the proposed game adjustment design. In games where the proposed game adjustments cannot be applied so straightforwardly (e.g. basketball), this study can serve to provide inspiration for more creative designs, such as altering the basketball court dimensions.

I also acknowledge that the proposed strategies might conflict with each other. For example, in this study the smaller table closer to the net altered the style of play of the stronger participant and this helped in moderating the influence of the player's actions over the opponent's performance. However, this change of style of play prevented the participants from acquiring useful table tennis skills, such as long strokes. Dynamic adjustments might be a possible solution to resolve this conflict and implement game adjustments that moderate the influence of the player's actions over the opponent's performance, and that allow acquiring useful table tennis skills.

This study also has the limitations of the study reported in chapter 4 (see 4.4.3): the assessment of the participants' skills using a pre-questionnaire, and the limited number of participants preventing an analysis of whether (and how) the motivation of the participants to practise physical activity influenced the engagement scores.

Although I used a statistical test to assess mismatched participants (see 5.2.3), I note that the test has limitations in detecting mismatched participants, when the distribution has a great standard deviation. In this study, I concluded that all pairs of participants were well matched observing that the distribution of the final score difference between participants in the no-adjustment had reasonably small variance yet not having any outliers.

Finally, the limitations of current technology required a manual adjustment of the bat size, with a limited amount of adjustments. However, the study of this game adjustment can serve as a future direction and opportunity for future designs, and is therefore relevant for those who would like to utilise digital technology to enhance player engagement in physical games.

5.5 Conclusions

To understand the design of effective balancing strategies for physical games, I conducted a study in a digitally augmented table tennis game to investigate how different game adjustments with different frequency updates impact game balancing and player engagement.

The main contributions of this work are insight into how game adjustments with different frequency updates affect the player experience and enhance player engagement in physical games; insight into how digital technology can be used as a design resource to enhance player engagement by adjusting the game dynamically in traditional physical games; and game design strategies to design engaging balancing in physical games.

This study will benefit game designers by providing an understanding of game balancing in physical games, which is also valuable for the sport community. Moreover, this study can inspire game designers who aim to merge digital technology and traditional sports for enhancing player engagement. I expect that the future ubiquity of technology will make the game adjustments, such as altering the playing field dynamically, available to a wide range of designers and sport practitioners. An understanding of the design of digital technology in sports will be important to design engaging physical games.

This study in chapter 5 shows the benefits of locating the table at the centre of the net. For example, it allows the game designer to moderate the influence of a player over the opponent's performance by altering the style of play of the disadvantaged player. However, a drawback I found in this adjustment is that it prevented the practice of long strokes, those strokes a player looks for when playing table tennis. This might indicate that altering the player's performance (e.g. player's strokes) can have some advantages and disadvantages. To understand how different ways of adjusting players' performance can influence player engagement and game balancing, in the next chapter I report results from a study that investigate the following two game adjustments: (i) in one adjustment, I used the same static table adjustment of the present study in order to alter players' performance and induce a player to play short strokes and adopt a more defensive style of play; (ii) in the other adjustment, I changed the playing surface area to one of the corners to encourage long strokes and a less defensive style of play yet easy to predict for the opponent.

Chapter VI

Case study 3: Understanding the effects of altering the performance of players when balancing exertion games

6.1 Introduction

In chapter 5 the table size and bat-head size adjustments reduced the score difference between participants and helped enhance player engagement. The study results showed a benefit of the table adjustment over the previously studied adjustments, i.e. asking the more skilled players to play with the non-dominant hand (see chapter 4): more control over the influence on players' performances. In table tennis, performance parameters that describe the outcome of one stroke are where the ball hits the table, the spin of the ball and the ball velocity [7]. In the study in chapter 5 I controlled the ball-hit location and influenced the style of the players, which helped in moderating the influence of one player's actions on the other's performance. Although altering the style of play was beneficial, one of the drawbacks was that it prevented the participants from performing long strokes; those strokes players usually aim for in a table tennis game. This strengthens the hypothesis that altering players' performances can impact game balancing and player engagement. This is a research gap derived from the last case study (see study in chapter 5).

The prior study could not address this research gap for a number of reasons. First, the aim of the previous study was not to evaluate the influence of different players' performances. Second, to evaluate the influence of different players' performances on game balancing and player engagement, it is necessary to evaluate game adjustments that encourage consistent performances. This was not possible with a bat adjustment where players' performances when playing with smaller bat-head sizes can be unpredictable. Also, dynamic adjustments can introduce variability of players' performances during the game.

To evaluate the effects of altering players' performances in exertion games, I evaluated two table adjustments because chapter 5 showed that a table adjustment can support game balancing and alter players' performances. Each table adjustment had a different location of the playing surface area.

The research questions this study aims to address are the following: **How does game adjustment design that alters the players' performances affect game balancing and player engagement in non-parallel games?** To address this question I defined a set of sub-questions. These following sub-questions are based on game adjustments that encourage different players' performances: (i) a defensive play and easy for the opponent to counter, and (ii) an aggressive play yet easy to predict for the opponent.

- RQ1: In which way do the different game adjustments influence players' performances?

- RQ2: Do different game adjustments that encourage different players' performances impact game balancing differently?

- RQ3: Do different game adjustments that encourage different players' performances impact player engagement differently?

- RQ4: Do different game adjustments that encourage different players' performances impact player engagement differently depending on players' skill status?

Prior work has strengthened the hypothesis that altering players' performances can impact on player engagement. Altering players' performances might also alter the gameplay. Gameplay refers to the challenges the players have to overcome and the actions that enable these players to overcome them [1, p. 251]. Prior work shows that the actions of the players during the game are important to understand player engagement [84, p.315] [15] [1, p.251]. In particular, Salen and Zimmerman state: "very often, when a game simply is not fun to play, it is the core mechanics that is to blame" [84, p.317]. The core mechanics generate the gameplay by introducing new challenges to players and by accepting players' actions.

Altering the gameplay can also influence the degree of how meaningful the game experience is, which is key for player engagement [84]. Salen and Zimmerman consider a game experience meaningful when players' actions relate to one another, and when the players can choose to perform an action from a rich set of meaningful actions [84].

Moreover, a meaningful experience is when there is a tight coupling between an action and an outcome, and this outcome is uncertain [84]. Altering players' performances can alter the number of actions the players can choose to perform and the uncertainty of the outcome. Prior work also shows that different body movements can affect the way players are engaged in the game [15]. Also, the ability to transfer real world knowledge to learn the movements of the game can influence player engagement positively [79]. Moreover, one of the determinants of player motivation in sport is the task to be performed [96]. This is not surprising since some tasks are more enjoyable than others. Finally, altering players' performances can influence the number of game mistakes. The perception of failure can impact negatively on players' experiences [49] [3]. This reinforces the hypothesis that altering players' performances and players' actions to overcome the challenge can alter player engagement.

The contributions of this study are two-fold: (i) providing insight into how game adjustments that alter players' performances can affect game balancing and player engagement; and (ii) offering two game design strategies for balancing exertion games through altering players' performances.

6.2 Methodology

In this section I focus on the aspects in which this study differs from the other case studies.

6.2.1 The game

As a follow-up of the study in chapter 5 I studied a digitally augmented table tennis game.

6.2.2 Study design

The study was a 2x2 split-plot design [55, p. 54] with two independent variables: table adjustment and players' skill status. I defined the table adjustment as a within factor with two levels. Each pair of participants played in two different table adjustments, which altered the playing surface area, as described in 6.2.4. The order of conditions was counterbalanced to avoid any order effect. I did not include the non-adjustment condition since the aim of the study was to investigate how different game adjustments that encourage different players' performances impact on player engagement and game balancing. For the second independent variable, I defined players' skill status as a between factor with two levels. I matched participants of different skill levels, so that in every match one was assigned as "the more skilled player of the match", and the other as "the less skilled player of the match".

6.2.3 Participants

I selected participants that had previously played the traditional table tennis game. I recruited 30 participants: 8 females and 22 males with an average age of M=23.6 years old and SD=3.83. All the participants selected were right-handed, which was important for the table adjustment design (see 6.2.4). The self-reported skill levels of the participants were: novice (1 participant), beginner (13), competent (6), proficient (9) and expert (1). I used this information to pair the participants. The objective was to create pairs of participants with as large as possible a difference in skill level between them participants in each pair. The pairs were as follows: novice vs. proficient (1 pair), beginner vs. proficient (8), competent vs. expert (1) and beginner vs. competent (5).

As I required self-assessment of participants' skills, there was a possibility of creating pairs whose skills were actually quite similar. Therefore, as explained in 3.2, I decided to discard the pairs whose participants' skill level difference was significantly smaller than that of the others in order to prevent evaluating pairs whose participants were too similar in skill. I checked the results of the final score difference between the participants of each pair in the two table adjustment conditions, and I looked for outliers. As I did not find any, I concluded there was a satisfactory difference between participants' skills in all pairs, and therefore did not discard any pair.

6.2.4 Table adjustment design to alter the performance of players

This study aimed to study the effects of altering players' performances when balancing exertion games. When altering players' performances to balance a game, it is important to understand in which ways we can alter it without compromising the players' experience. There are different determinants of players' performances in sports, including their skills, fitness and psychological factors [5, p.108] [101] [4]. However, altering these factors directly can be challenging in the real world. Therefore, in this research, I opted to alter the outcome of the execution of a task instead, such as the stroke in table tennis. The parameters that describe the outcome of a stroke in table tennis are the hit-ball location, the ball spin and the ball velocity [7]. Among these parameters, I chose to alter the hit-ball location, which can be controlled more easily by the game designer using technology. I also thought it could encourage different styles of plays and thus be suitable for investigating the effects of different ways of altering players' performances on game balancing and players' engagement.

I adjusted the playing surface area to induce different hit-ball locations resulting in different styles of play. One table adjustment aimed to influence the more skilled players to play more defensively and to perform short strokes that would be easy for the less skilled players to counter. This was achieved by reducing the playing surface to an area close to the centre of the net (Figure 6.1 right). I will refer to this table adjustment as **centre adjustment**. The other table adjustment aimed to encourage the more skilled players to perform long strokes and be more aggressive, yet easier for the less skilled players to predict and get ready for countering. This was achieved by reducing the playing surface to one corner of the table. I will refer to this table adjustment as **corner adjustment** (Figure 6.1 left).

Figure 6.1: Case study 3. Table adjustment: table located at one of the corners (left), and table located at the centre of the net (right)

Each table adjustment can influence game balancing differently, not only by the challenge imposed on the less skilled players in countering the strokes of the more skilled players, but also by the challenge imposed on the more skilled players in playing with the restriction in place. The game adjustments can also influence players' engagement differently. For example, one restriction can be more suitable for levelling players' skills, while the other can be more useful for play practice, i.e. the practice of a sport in a playful manner [54]. Performing, improving and testing skills can be important for player engagement in a sport [87].

In the centre adjustment (Figure 6.1, right) I used 30% of the size of the original table tennis table which I found was enough to induce defensive play and strokes that are easy to counter. The rationale for this decision is that this study is focusing on the influence of different players' performances rather than the right amount of game adjustment for balancing. To determine the size of the table in the corner condition that facilitates a similar difficulty level as in the centre condition in placing the ball in the playing area. I conducted a pre-experimental study. I took 6 participants (3 pairs) and asked them to play an 11-point game in the centre condition with 30% of the size of the regular table tennis table, and different sizes of the corner condition: 30%, 15% and 7.5% of the regular table. I decided the table size of the corner conditions should be the same or smaller that of the table size of the centre condition because I noticed that some zones of the table in the centre condition are almost unused because of the proximity with the net. In this pre-experimental study I also decided to place the target location area on the right corner (see Figure 6.1) because the less skilled players would find it easier to return the ball using the forehand rather than backhand (with right-handed participants). In this pre-experimental study I asked participants to rate the perception of difficulty [1-"Very easy", 5-"Very hard"] in placing the ball on the table in each of the four conditions. The results of the pre-experimental study showed that the table size of the corner condition would have 20% of the size of the regular table tennis table to match the similar difficulty level of the center condition.

6.2.5 Material and setup of the study

I used the equipment and technological implementation described in 3.4.1.

6.2.6 Procedure

Participants warmed up for 6 minutes. First they played without any adjustment and then with the two table adjustments (2 minutes per condition). I requested the participants to play competitively. After they finished the warming up, they played 21-point games in each table adjustment as experimental conditions. The order of the table adjustments was randomized to prevent any order effect. I opted for a 21-point game instead of an 11-point game to allow sufficient time for the participants to experience each table adjustment. After each game, the participants completed a questionnaire that assessed their engagement. Finally, after finishing all conditions, the participants were interviewed in pairs using a semi-structured interview.

6.2.7 Data collection and analysis methods

As this study aimed to understand the effects of altering players' performances to game balancing and player engagement, I collected information about participants' performances to assess whether the two table adjustments encouraged different players' performances beyond the hit-ball location. For this I measured the average ball velocity of the strokes of each participant in each point and in each table adjustment. I used this information to calculate the average ball velocity for each table adjustment. I report the results of the magnitude of the ball velocity. To measure ball velocity I measured the elapsed time between consecutive ball-hits on each side of the table and the distance between these two hit locations. I note that these measurements did not provide the exact velocity as I only took into account a 2D trajectory of the ball instead of the 3D trajectory. However, I the obtained measurement might be a good approximation of the ball velocity. I used paired t-tests to compare ball velocity between the two table adjustments.

I also used qualitative measures to further assess participants' performances. Semi-structured interviews were conducted with questions to assess the variety and types of shots participants performed and their style of play. During each experimental test, I also took note of the observations regarding participants' style of play, such as defensive or aggressive play. The observations were conducted using the camera installed on the ceiling that captured the table and the ball, and these notes were used in the semi-structured interviews.

I collected information about game balancing, including score difference and win/ lose ratio. The score difference was evaluated using a paired t-test (after validating the t-test assumptions). The win/lose ratio was evaluated using the Fisher's exact test to evaluate whether there was a relationship between the table adjustment and the number of matches won by the more skilled participants. To further evaluate game balancing I used qualitative data from the semi-structured interviews for assessing whether participants perceived one table adjustment leveled participants' skills more than the other table adjustment. Since in a non-parallel game a player's performances can influence the other player's performance, I decided to evaluate whether game adjustments helped mediating this influence. For this I measured and compared the average number of hits per point in each of the table adjustments. I used the Wilcoxon test since the data did not meet the assumptions of the t-test. I expected that the results of the average number of hits per point and participants' reports on which table adjustment leveled the participants' skills better will be aligned.

To collect feedback on the experience of participants I used the engagement scale questionnaire (five-point scale) from the O'Brien model of engagement [74] (see 3.3.1). The questionnaire is in Appendix B. The player engagement scale in this study had high reliability (Cronbach's-α=0.8). For analysing the engagement scores I used repeated measures ANOVA with the table adjustment as a within-subjects factor and players' skill status as a between-subjects factor. Prior to the repeated measures ANOVA I also performed the appropriate tests to validate their assumptions. For all the tests the significance level was set at α=0.05.

In the semi-structured interviews, I also assessed which table adjustment participants preferred and the reasons for their preference in order to better understand participants' engagement. The semi-structured interviews were conducted at the end of the experiment, i.e. after participants played both conditions. For the analysis of the semi-structured interview data I used quasi-statistics analysis to identify the most frequently mentioned reasons for preferring one table adjustment over the other [13].

6.3 Results

6.3.1 Players' performances

RQ1: In which way do the different game adjustments influence players' performances? The results on participants' performances include ball velocity, the variety and types of participants' strokes and participants' style of play.

Ball velocity: The paired t-test showed significant differences regarding the average magnitude of the ball velocity (measured in m/s) between the centre adjustment (M=2.00, SD=0.35) and the corner adjustment (M=2.61, SD=0.45), $t(29) = 8.06, p < 0.01$.

Variety and types of strokes: Reports from participants revealed that each table adjustment afforded a different number and type of strokes. Sixty per cent (9/15) of the more skilled participants reported the types of strokes to be different in the two table adjustment conditions, and 20 % (3/15) of the more skilled participants reported they could practise a greater variety of strokes in the corner adjustment. Examples of participants' reports regarding the play in the corner condition include: "*I can do my big forehand*", "*I can play long strokes*", "*I can play like a real game, perform normal strokes*" and "*I can smash*". In contrast, the reported types of strokes available in the centre condition were different: "*In the centre is just tap over the net*", "*I could not do my big forehand*", "*I could not do the shots I usually do in the table tennis*".

Players' style of play: While the participants were playing, I observed that the attitude of the more skilled participants in the corner condition was different from the centre condition. In the centre condition, the participants seemed to be more passive, as if they were waiting for opponents' mistakes instead of trying to win the point. This seemed to be the opposite in the corner condition. This was confirmed by a participant report, saying "*in the centre is like keeping the rally going down rather than actually trying to win the point (. . .) it is just tap it over*". Another participant said "*I liked the first condition (corner) because it allowed me to be more aggressive*".

These results show that the game adjustments induced different players' performances. With the corner adjustments the ball moved faster than the centre adjustment. In addition, these two different game adjustments induced different types of strokes and styles of plays.

6.3.2 Game balancing

RQ2: Do different game adjustments that encourage different players' performances impact game balancing differently?

Score difference: The score difference of the participants is summarized in Figure 6.2. The score difference (in absolute value) was significantly greater in the centre condition (M=8.9, SD=4.6) than in the corner condition (M=5.7, SD=2.7), $t(14) = 2.49, p = 0.026$.

Win-lose ratio: The more skilled participants won 33.3% of the matches (5/15) in the centre condition, and 80% of the matches (12/15) in the corner condition. The Fisher's exact test indicated that the table adjustment had a significant influence on the number of matches won by the more skilled participants ($p = 0.025$).

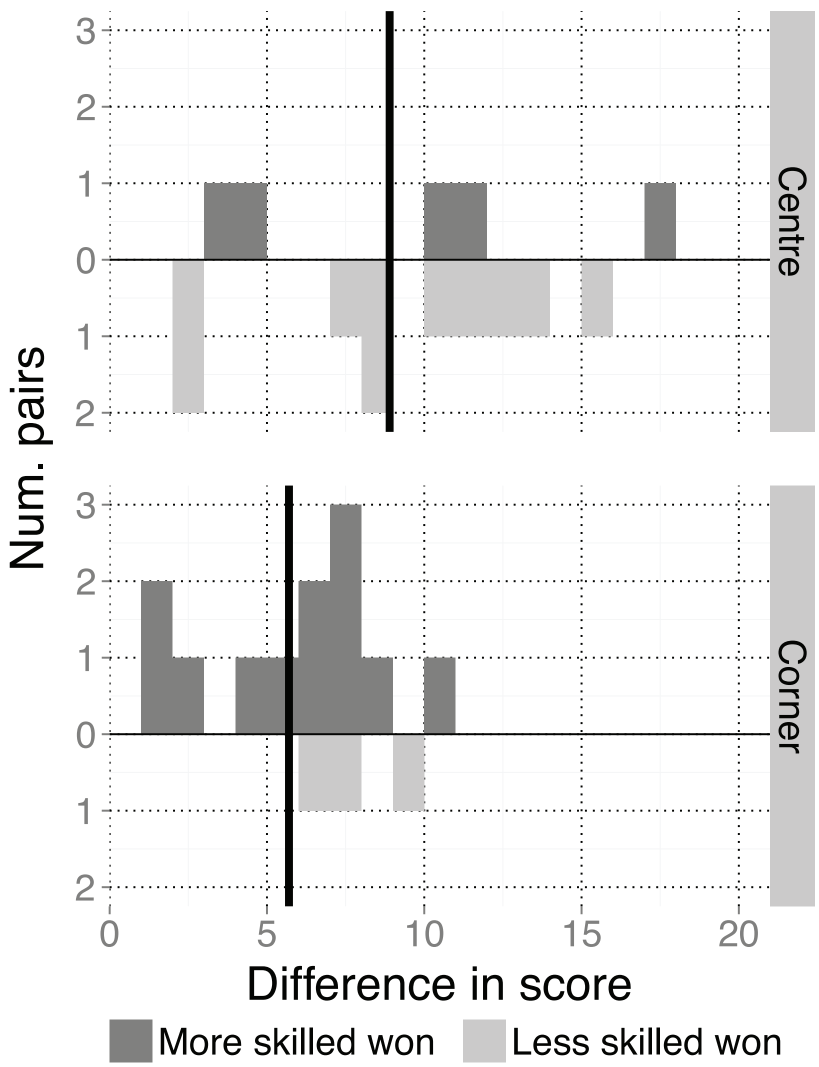

Figure 6.2: Case study 3. Score difference between the centre condition and the corner condition. The vertical black line shows the average of the score difference

Leveling players' skills: Sixty per cent of the participants reported that the centre condition leveled players' skills more efficiently, while 26.7% reported the corner condition helped in leveling level players' skills more efficiently, and 13.3% reported no difference between the two table adjustments.

Average hits per point: The Wilcoxon test showed significant differences regarding the average number of hits per point (per participant) between the centre condition (M=2.03, SD=0.61) and the corner condition (M=1.35, SD=0.32), $W = 460, p < 0.01$.

6.3.3 *Player engagement*

RQ3: Do different game adjustments that encourage different players' performances impact player engagement differently? Taking into account both the more skilled participants and the less skilled participants, player engagement did not significantly differ between the two table adjustments, $F(1, 28) = 2.56, p = 0.12, \eta^2_G = 0.02$.

RQ4: Do different game adjustments that encourage different players' performances impact player engagement differently depending on the player skill status? The more skilled participants reported higher engagement scores in the corner condition (M=3.90 , SD=0.33) than in the centre condition (M=3.61, SD=0.51), see Figure 6.3. However, the less skilled participants reported lower engagement scores in the corner condition (M=3.66, SD=0.38) than in the centre condition (M=3.72, SD=0.42). The different effect of the centre and corner conditions for the more skilled and less skilled participants was significant $F(1, 28) = 5.75, p = .023, \eta^2_G = 0.04$.

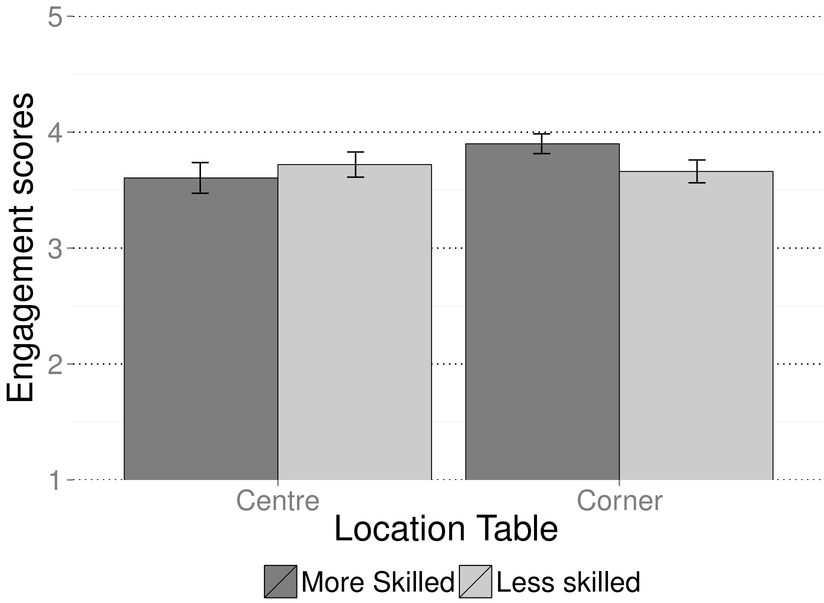

Figure 6.3: Case study 3. Mean and error bars of engagement scores of the more skilled participants and less skilled participants in the centre and corner adjustments

The results of the engagement scores were in line with participants' reports about their preferred table adjustment in the semi-structured interviews. Seventy-three per cent (11/15) of the more skilled participants preferred the corner condition, while 20% (3/15) preferred the centre condition. In contrast, 47% (7/15) of the less skilled participants preferred the corner condition, and 40% (6/15) of them preferred the centre condition. Therefore I conclude that the different game adjustments impacted differently on the more skilled and less skilled participants. To understand this finding, I report in which way game adjustments impacted player engagement.

In the interview, the more skilled participants reported two main ways in which the table adjustment affected player engagement. First, players' performance encouraged in the corner condition was perceived as more engaging for 80% of the more skilled participants than in the centre condition. For example, participants reported that the corner condition allowed a greater variety of shots (e.g. saying "*definitely I liked more the corner condition because it allowed to play a variety of shots rather than tap over the net*"), and it encouraged more engaging types of shots (e.g. saying, "*the type of shots is preferable in the corner*", "*I like the corner condition because I could hit the ball harder*", "*I prefer playing long shots*", "*I like play more in the corner, play as a normal condition*", "*I prefer the corner condition because I can practise my shots better, practise something I am used in table tennis*"). However, participants also reported downsides of the corner condition. One of the participants reported that this condition allowed him to smash and play aggressively, which increased the number of interruptions and shortened the game points: "*I found when the table was on the corner I could smash and I was better (. . .) the game was less equal and less interesting because when we played and I smashed, I win and the play stopped*".

The less skilled participants' engagement was similar between both table adjustments. The three most reported reasons for preferring one table adjustment over the other were the perception of challenge (7 participants), players' performance (6) and the sense of control (3). These reasons were sometimes used to justify the preference for one table adjustment, and at other times to justify the preference for the other. For example, four participants preferred the centre condition because it facilitated the task of returning the ball (e.g. saying "*I like the centre, it was easier to hit*"), but another three preferred the corner condition because it provided a greater challenge and allowed them to test their skills. Finally, three participants preferred the centre condition because the table adjustment facilitated a greater sense of control. These results show the great diversity in the type of players and their preferences.

6.4 Discussion

This study shows how game adjustment design that alters the player's performance affects game balancing and player engagement in the table tennis game. The results show that the two table adjustments altered players' performances differently. Restricting the hit-ball location influenced the style of play of the participants. Finally, participants reported that in the corner condition they could practise different types of strokes and also try a greater variety of strokes than in the other table adjustment.

The table adjustments had a significant impact on game balancing (see 6.3.2). I identified two ways of how the restriction on players' performance (e.g. altering the hit-ball location in table tennis), can contribute to balancing the game: through the degree of challenge imposed by the restriction in place, and through the style of play the restriction encouraged in the more skilled players.

The degree of challenge imposed by the restriction: Different restrictions on players' performance can alter the degree of challenge they experience. This can influence the number of game mistakes, such as in placing the ball out of the playing surface area, and it can contribute to balancing the score and the win/lose ratio.

The style of play encouraged by the restriction: A restriction on players' performance not only can influence the challenge imposed by this restriction, but can also alter the style of play of the more skilled players. This modulation of the style of play can be seen as the degree of **assistance** to the less skilled players. In this study, the defensive style of play encouraged by the centre condition helped less skilled participants to return the ball to the opponents' table. This influenced participants' perceptions about how levelled the participants' skills, which supports the findings in chapter 5.

Both table adjustments in this study challenged the more skilled participants with the restriction imposed and induced game mistakes. This challenge influenced the final score difference in both table adjustments. However, the style of play induced in the centre condition helped the less skilled participants in countering the play of the skilled participants. That is why the less skilled participants tended to win more in the centre condition than in the corner condition (see Figure 6.2).

The table adjustments not only influenced players' performance, but also impacted upon player engagement. For the more skilled participants, the engagement scores were higher in the corner condition than in the centre condition. The reason is mainly because of the impact of the table adjustments on players' performance: style of play, variety of shots and the type of shots (see 6.3.3). This supports the hypothesis that the way players are challenged and constrained is critical for player engagement in exertion games. This aligns with prior work that shows that different body movements can influence how players are engaged [15].

In summary, different table adjustments affected game balancing and player engagement differently because of the different players' performance these adjustments encouraged. Based on these results, I present two strategies for balancing exertion games through restricting players' performance.

6.4.1 Game design strategies

While there are other ways for balancing a game, in non-parallel games, a restriction on the more skilled players' performance can often be necessary. The two design strategies focus on the insights gained from the two game adjustments used in this study that altered players' performance. The proposed strategies complement each other, and designers should take the insights of this work as inspiration to inform future game adjustment designs.

Strategy 1: induce game mistakes by restricting players' performance

The game mistakes induced by the game adjustments depended on the challenge imposed on the players in playing with them. In this study, the more skilled participants often failed to place the ball in the playing surface area. Although I did not measure the number of scored points by the less skilled participants through the mistakes of their opponents, I believe that the number of game mistakes might have been different in the two table adjustments. The number of game mistakes induced by a restriction can depend on the familiarity of the players in playing with the restriction imposed.

Altering this challenge and thus altering the game mistakes can be effective for game balancing, but game designers should be aware that balancing through game mistakes can have some risks. Prior work showed that certain perceptions of failure can have a negative impact on player experience [49], and losing frequently can reduce players' interest in the game [3].

Advantages: This strategy can support different gameplay of the players and thus appeal to a great number of players. For example, it can be implemented when the game adjustment encourages strokes that are easy to counter (e.g. centre condition in the study) and those strokes that are more difficult to counter for the opponent player (corner condition or strokes in the back area of the court in squash [100]). Therefore this strategy can be useful for play practice: the practice of the sport through a playful manner [54].

Disadvantages: The main disadvantage of this strategy is that it does not mediate the influence of the more skilled players' performance on the less skilled players' performance. This can impact negatively on the less skilled players' experience owing to the difficulties in countering the "attacks" of the opponent players (see 6.3.3).

Strategy 2: assist the less skilled players by altering players' style of play

This strategy was identified in chapter 5 as a way to enhance player engagement in non-parallel games because it indicates a way to mediate the influence of a player's actions over the other player's performance. Here I report this strategy again because this strategy can be used when restricting players' performance, and because this study provides more information about the implementation of this strategy, such as its strengths and weaknesses.

This strategy focuses on altering the style of play of the more skilled players in a way that prevents a gameplay that is difficult to counter for the less skilled players, such as in the centre condition of this study. This strategy can be more suitable than the previous described strategy when the difference between players' skills is great, because it can not only impose an increased challenge on the more skilled players in playing with a restriction, but can reduce the skill level differences between the players by altering the style of play.

Advantages: This strategy can mediate the influence of the more skilled players' performance over the opponents' performance and therefore it can level players' skills efficiently. It can also promote longer game rallies (see 6.3.2).

Disadvantages: The more skilled players' actions, such as the strokes performed, might not be as engaging to perform as those actions that are difficult to counter for the opponent player (see 6.3.3).

6.4.2 Generalization of the results and limitations

I studied two game adjustments that restricted the more skilled players' performance. The derived strategies based on this study are not an exhaustive list and future work will be able to extend the proposed strategies by studying other players' performance. However, the study results can be a starting point to understand the effects of varying players' performance and their influence on game balancing and player engagement.

The proposed game adjustment designs can be applied more straightforwardly in some games (e.g. tennis or squash), than others (e.g. basketball). Despite this limitation, the proposed game design strategies can be useful to a great variety of non-parallel games. For example, in martial arts, I envision the game adjustments can restrict the more skilled players with hits that vary in the level of difficulty to counter. Also, the judges might penalize the score of the more skilled players when these players hit in restricted areas or perform movements that are not allowed. In games like squash, the game design adjustments can be applied in a more straightforward way. For example, to apply the proposed design game strategies, a game designer could take the different court zones that are difficult to counter, such as the back of the court (see [100]), or a zone where it can be easily countered by the opponent, such as the centre of the court. Based on the understanding of the effects of playing in different court zones, such as in the ability to counter the strokes of a player, it is possible to design game adjustments that assist the less skilled players. Also, game designers can alter a court's dimensions to encourage game mistakes.

This study also has the limitations of the study reported in chapter 4 (see 4.4.3): the assessment of the participants' skills using a pre-questionnaire, and the limited number of participants preventing an analysis of whether (and how) the motivation of the participants to practise physical activity influenced the engagement scores.

Although I used a statistical test to assess mismatched participants (see 6.2.3), I note that the test has limitations in detecting mismatched participants when the distribution has a great standard deviation. In this study, I concluded that all pairs of participants were well matched observing that at least the distribution of the final score difference between participants in the corner condition had reasonably small variance yet did not have any outliers.

6.5 Conclusions

I conducted a study to investigate how digital technology can adjust players' performance with different styles of play and their effects in game balancing and player engagement in table tennis.

The contribution of this work is providing insight into how game adjustments that facilitate different players' performance affect game balancing and player engagement in an exertion game; and providing two game design strategies for balancing exertion games through restricting players' performance.

This study shows that there are different ways game designers can alter players' performance, and each way has its own advantages and disadvantages. In addition to that, different players might have different reasons to play a game (e.g. for training). This shows why understanding the implications of implementing each of the strategies can be important for exertion game design to enhance player engagement.

The contribution of this work benefits game designers and the sport community in providing an understanding of how game adjustments that alter players' performance can support game balancing and influence player engagement.

This study shows a trade-off in each of the strategies proposed. One strategy could be more suitable for leveling the skills, and the other for practising skills and encouraging more engaging movements for the more skilled players. Since the use of digital technology can have many advantages, such as the alteration of players' performance dynamically, in the next chapter I report a study that investigates dynamic adjustments that can take care of this trade-off, and provide further insights into the effect of adjusting players' performance on game balancing and player engagement.

Chapter VII

Case study 4: Understanding the relationship between the restriction on a player's performance and player engagement when balancing non-parallel games

7.1 Introduction

In chapter 6 I identified two ways in which the restriction on players' performance, such as by altering the hit-ball location in table tennis, can contribute to balancing the game: i) through the degree of challenge imposed by the restriction in place, and ii) through the style of play the restriction induces on the more skilled players. The degree of challenge imposed by the restriction can induce game mistakes, which can balance the score and the win/lose ratio. Prior studies (reported in chapters 5 and 6) showed that altering the style of play of the more skilled players can be used to assist the less skilled players in countering the performance of the more skilled players.

In this study I further investigate the research question addressed in chapter 6: **How does game adjustment design that alters the player's performance affect game balancing and player engagement in non-parallel games?** Although I identified these two ways in which the restriction on players' performance can help balance a game, there is still a missing understanding of how game adjustments, based on altering the degree of challenge in playing with a restriction, and the style of play induced by the restriction, influence game balancing and player engagement. This chapter presents a study that aims to fill this gap by enhancing our understanding of the effects on game balancing and player engagement when (i) we alter the degree of challenge by imposing a restriction, and (ii) we alter the style of play of the more skilled players as a means of modulating the degree of assistance given to the less skilled players. The ultimate goal is to enhance our understanding of the design of dynamic adjustments based on the restriction of players' performance. To further investigate the main research question I define the following sub-questions:

- RQ1: How does the style of play imposed on the more skilled players affect game balancing?
- RQ2: How does the style of play imposed on the more skilled players affect player engagement?
- RQ3: How does the degree of challenge of a restriction imposed on the more skilled players affect game balancing?
- RQ4: How does the degree of challenge of a restriction imposed on the more skilled players affect player engagement?
- RQ5: Regarding player engagement, is there an interaction effect between the style of play and the degree of challenge of a restriction imposed on the more skilled players?
- RQ6: Regarding game balancing, is there an interaction effect between the style of play and the degree of challenge of a restriction imposed on the more skilled players?
- RQ7: How should dynamics adjustments based on a restriction of players' performance be designed to improve game balancing?
- RQ8: How should dynamics adjustments based on a restriction of players' performance be designed to enhance player engagement?

The contribution of this study is an understanding of the relationship between the restriction on players' performance and player engagement, which can help in designing engaging balancing adjustments in non-parallel physical games.

7.2 Methodology

In this section I focus on the aspects in which this study differ from the other case studies.

7.2.1 The game

As a follow-up of the study in chapters 5 and 6, I studied a digitally augmented table tennis tennis game.

7.2.2 Study design

The study design had a split-plot design [55, p.54]. I evaluated two dynamic table adjustments (see Figure 7.1). Each adjustment had four different table configurations. Each participant played games in both table adjustments, playing from one to four of the table configurations for each adjustment. Each configuration imposed a different restriction on the more skilled players' performance (e.g. different playing surface area sizes and surface area locations). The table configurations for a pair of participants depended on their score differential during each game. The score differential intervals shown in Figure 7.1 were decided based on the following two criteria: (i) I did not want to change the game configuration at every point because this might have created some confusion to the players, as some participants commented in a pre-experimental study; and (ii) I wanted to maximise the number of participants reaching the four configuration.

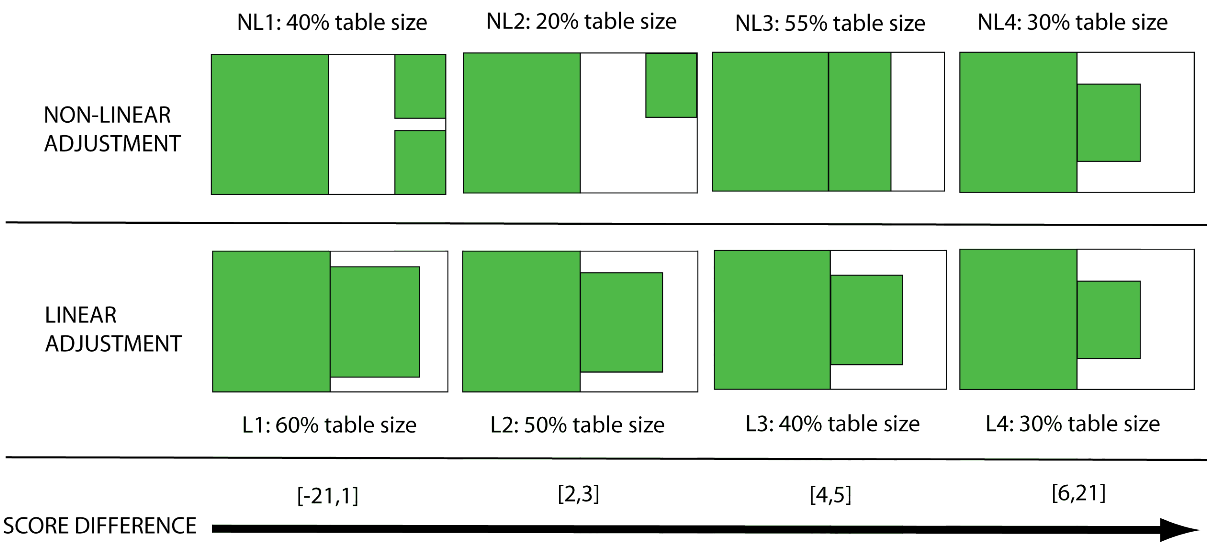

Figure 7.1: Case study 4. Table adjustments (linear and non-linear adjustment), and table configurations of the linear adjustment (L1, L2, L3 and L4) and the the non-linear adjustment (NL1, NL2, NL3 and NL4). The changes between table configurations depended on the score difference between the participants. A negative score was defined as when the less skilled participant had a higher score than the more skilled participant

In this study I also defined players' skill status. Before every match one participant was assigned as "the more skilled player of the match", and the other as "the less skilled player of the match". This was determined by assessing each participant's skill level using a pre-questionnaire, and was used to choose which participant had to play with the disadvantage in each pairing.

7.2.3 Participants

I selected participants who had previously played table tennis. I recruited 14 female and 37 male participants, with an average age of M=25.9 years and SD=6.9. The participants rated their skill levels as: novice (2 participants), beginner (16), competent (18), proficient (13) and expert (2). Eight participants were grouped as skilled participants who were (or had been) members of table tennis clubs. I used the information from the pre-questionnaire (see 3.2) to pair the participants. The objective was to create pairs of participants with as large as possible a difference in skill level. Of the 51 participants, 26 acted as "the more skilled participant of the match". The pairs were as follows: novice vs. competent (1 pair), novice vs. proficient (1), beginner vs. competent (13), beginner vs. proficient (5), competent vs. proficient (6), competent vs. expert (1), and proficient vs. expert (1).

I examined 28 matches. Although I first tried to pair two new participants in each new experiment, in 5 experiments a participant failed to attend and I had to find another participant. In these cases I took someone who had previously participated and whose self-reported skill level had been assessed. However, any participant who repeated the experiment was used only as a player, without any player engagement evaluation involved.

As I required self-assessment of participants' skills, there was a possibility of creating pairs whose skills were actually quite similar. Therefore, as explained in (see 3.2), I decided to discard the pairs whose participants' skill level difference was significantly smaller than the other pairs to prevent evaluating pairs whose participants were too similar in skill. I checked the results of the final score difference between the participants of each pair in the game played without any adjustment, and I looked for outliers. As I did not find any, I concluded there was a satisfactory skills difference in all pairs and therefore did not discard any pair.

7.2.4 Table adjustment design

I designed two different table adjustments (linear and non-linear), each with four different table configurations (see Figure 7.1). Each configuration imposed a different restriction on the more skilled players' performance. I altered the **size of the playing surface area** to alter the degree of challenge, and the **location of the playing surface area** to alter the style of play as a means of modulating the degree of assistance given to less skilled players in countering the more skilled players' play (see Figure 7.2). For this study, the degree of assistance for the less skilled players was implemented through the degree of defensive play induced on the more skilled players. I induced a higher degree of defensive play by restricting the playing surface area to be close to the net. The previous finding supported that the defensive play induced by restricting the playing surface area to be close to the net can help the less skilled players counter the more skilled players' performance (see chapters 5 and 6).

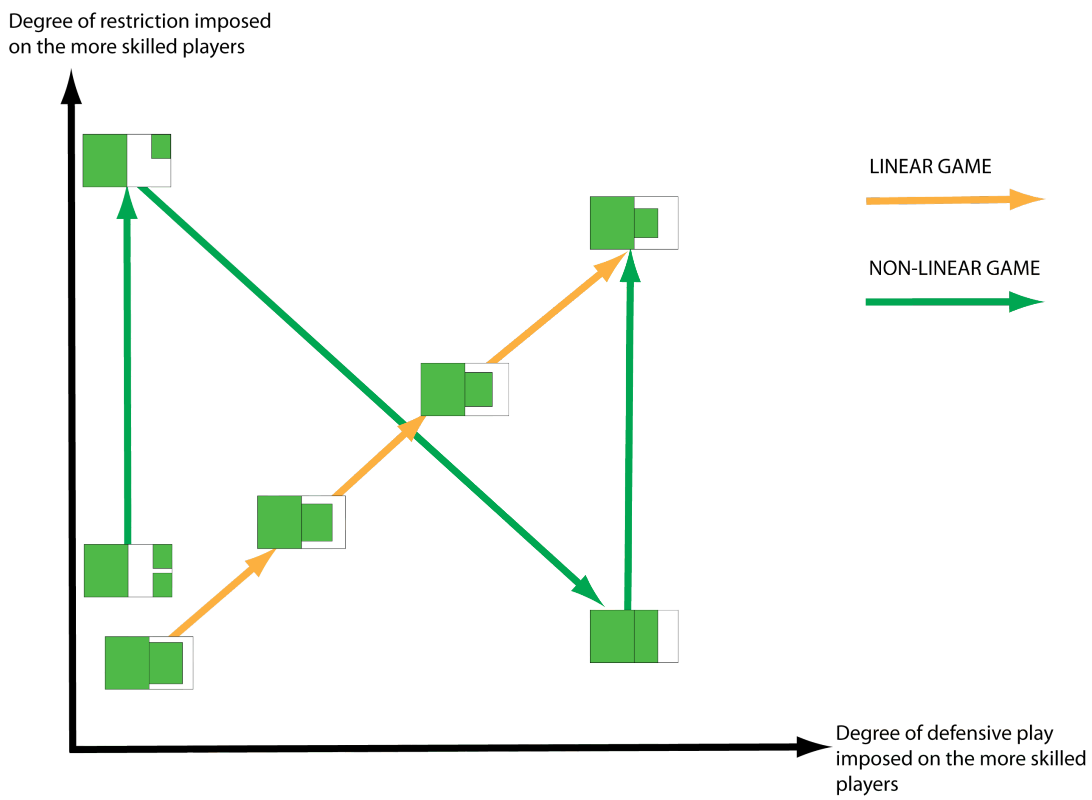

Figure 7.2: Case study 4. Expected degree of defensive play imposed on the more skilled players and degree of restriction imposed on the more skilled players in each of the different table configurations

The linear table adjustment progressively reduced the playing surface area size and altered the location of the playing surface area closer to the net as the score difference became greater in favour of the more skilled players. I used the non-linear table adjustment to study individual effects of altering the playing surface area size and location.

Players' serve

The more skilled participants were encouraged to serve, in both linear and non-linear adjustments, close to the net in order to facilitate the engagement of both players in each game point. This was achieved by displaying a serving surface area of approximately 40% of the size of the regular table tennis table only during the serve of the more skilled players. This serving surface area was placed close to the centre of the net (similar to the table configuration of the linear table adjustment).

7.2.5 Material and setup of the study

I used the equipment and technological implementation described in 3.4.1. However, in the present study, the software was further developed so that the number of points played in each table configuration and further relevant information could be stored in the database. For each point, the software saved the current players' score, the number of strokes per player, the average ball velocity and the table configuration in which this point was played. This allowed me to obtain the number of points won by each player and calculate average ball velocity per player for each table configuration. The environmental setup was the same as described in 3.4.2.

7.2.6 Procedure

Participants warmed up for 8 minutes, trying out all eight table configurations. During this time I requested that the participants play competitively. After warming up, the participants played a 21-point game without any adjustment, and two further 21-point games, one each with the linear and non-linear table adjustments. The order in which the participants played the linear and the non-linear adjustment was counterbalanced to avoid any order effect. After each table adjustment was played, the adjustment and the different table configurations were evaluated. At the end of the experiments participants were interviewed in pairs using a semi-structured interview to assess which table adjustment was preferred and their reasons for their preferences, to understand the player experience better.

7.2.7 Data collection and analysis methods

In this section I explain the steps followed and analysis methods used to evaluate (i) the relation between the table configurations of each table adjustment and the participants' ratings about the defensive play these imposed, and the degree of challenge imposed by the table configurations on the more skilled participants (see Figure 7.3); (ii) players' performance; (iii) game balancing, and (iv) player engagement. In all the tests, the significance level was set at α=0.05.

I used planned contrasts instead of post-hoc pair-wise comparisons when comparing conditions such as table configurations with predefined expectations of the results and a predefined set of comparisons to be made. An example is when I evaluated the defensive play in the different table configurations. Otherwise, I used post-hoc to do all the pair-wise comparisons.

I used a MultiLevel Model (MLM) as an evaluation test, instead a other more traditional test such as the standard ANOVA, when I had incomplete data (e.g. when I evaluated table configurations that some participants did not play). A MLM has the ability to better handle missing data [36, p. 860].

Table configurations and their effect on the style of play and the degree of restriction on the more skilled players

I evaluated whether the different table configurations had the expected effects on the defensive play imposed, and the degree of challenge in playing with the restriction in place (see Figure 7.2). After the participants had completed a match in each of the table adjustments, I asked them to position each table configuration played in the space shown in Figure 7.3. Participants' ratings were used to measure the effect of the different table configurations on the style of play of the more skilled participants, and on the degree of restriction imposed on the less skilled participants (disadvantaged participant). I used a MLM and planned contrasts for this analysis.

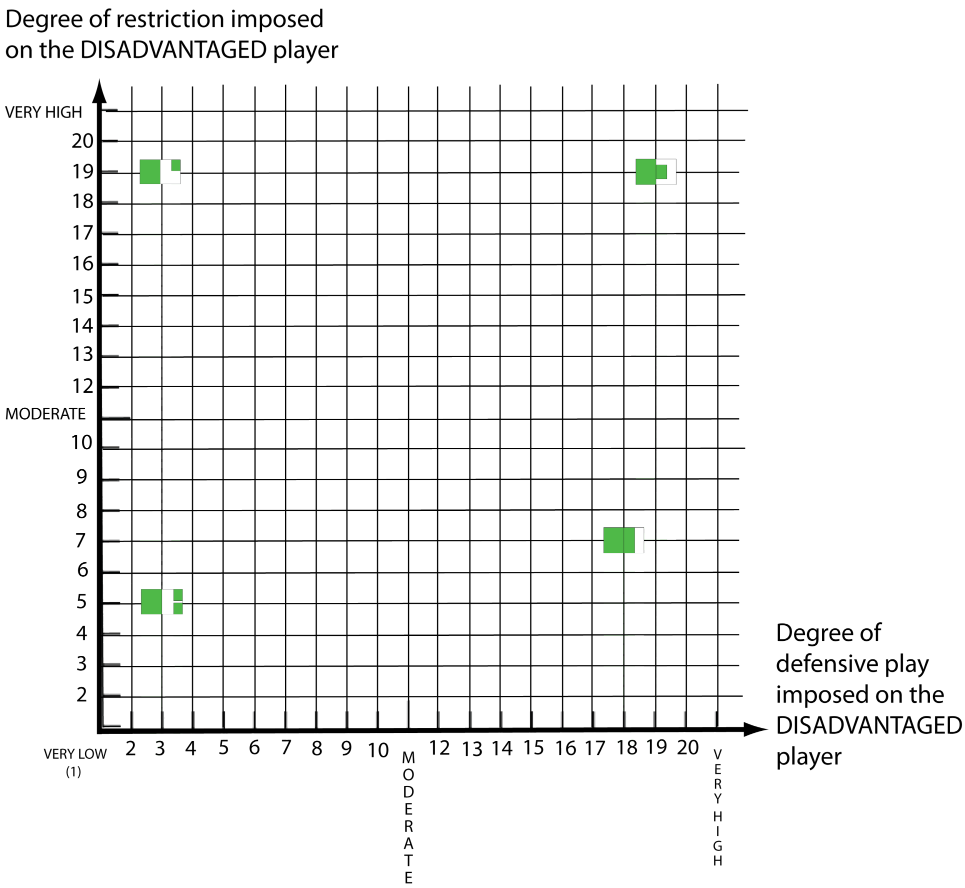

Figure 7.3: Case study 4. Example of a participant's ratings of the degree of restriction imposed, and the degree of defensive play imposed on the disadvantaged (more skilled) player

Players' performance

I measured the number of points played in each table configuration for each table adjustment. I used repeated measurements ANOVA (after validating its assumptions) and post-hoc with Bonferroni correction for this analysis.

I measured how the different table adjustments affected the way participants played in comparison to the no-adjustment condition by measuring the average ball velocity of the strokes of each participant in each point, in each table adjustment and in each table configuration. I used this information to calculate the average ball velocity in each table adjustment, and in each table configuration. I report the results of the magnitude of ball velocity. I used MLM models and planned contrasts for the analysis of the ball velocity. To measure the ball velocity I measured the elapsed time between consecutive ball-hits on each side of the table and the distance between these hit locations. This measurement does not give the exact speed of the ball as the analysis only takes into account a 2D trajectory instead of the 3D trajectory. However, this measurement might be a good estimation of the true ball velocity.

Game balancing

I measured the score difference and the win/lose ratio for the more skilled participants in the no-adjustment condition, and in the linear and non-linear table adjustments. The no-adjustment condition was included in the game balancing analysis to have a baseline comparison. I applied the Friedman test to analyse the score difference, and used post-hoc tests with Bonferroni correction for pair-wise comparisons. The Fisher exact test was used to evaluate any relationship between the number of matches won for the more skilled participants between the linear, non-linear adjustments, and no-adjustment conditions.

I also measured the average number of hits per point for each pair as a measurement of the length of the game rallies, on the assumption that the average number of hits per point could be a good indicator of how well balanced the participants' skills were. I applied the Friedman test and post-hoc with Bonferroni correction for this analysis.

Finally, I measured the win percentage of the more skilled participants in each table configuration. I used a MLM model and planned contrasts for this analysis.

Player engagement

I evaluated player engagement for each table adjustment (linear and non-linear) with the engagement scale questionnaire (five-point scale) from the O'Brien model of engagement [74] (see 3.3.1). The questionnaire is in Appendix B. Player engagement was evaluated after each table adjustment was played. Cronbach's-α for the engagement scale in our study had high reliability, $\alpha = 0.85$. Since the engagement scores were not normally distributed, I used the Wilcoxon test to compare the engagement between the two table adjustments.

In addition to the player engagement questionnaire, I asked participants in semi-structured interviews which table adjustment they preferred most and the reasons for this choice. These interviews were conducted at the end of their involvement in the experiment. The interviews provided insights about how each table adjustment influenced player engagement and player experience. I used the Fisher's exact test to see if the selection of the most preferred game differed significantly between the more skilled and less skilled participants.

After each table adjustment was played, I also evaluated individual table configurations by asking the participants to rank the different table configurations played according to their preference, taking into account player engagement. In semi-structured interviews conducted after each table adjustment was played, the participants were also asked to explain the reasons for their rankings.

7.3 Results

7.3.1 Validation the game adjustment designs

I evaluated whether the different table configurations (Figure 7.1) induced the expected defensive play from more skilled players, and the degree of restriction expected to be experienced by the more skilled players (Figure 7.2). The results are shown in Figure 7.4.

I defined a MLM model with the degree of defensive play as a dependent variable, and the different table configurations as the independent variable. I performed a planned contrasts analysis with the comparisons shown in Figure 7.5.

The linear adjustment did not significantly differ in terms of defensive play rated by participants compared to the non-linear adjustment (Cr. 1: $b = -0.21, t(254) = -0.84, p = .40, r = .05$). L1 imposed a significantly lower defensive style of play than the other linear table configurations (Cr. 2: $b = 1.53, t(254) = 8.76, p < .001, r = .48$); L2 imposed a significantly lower degree of defensive play than L3 and L4 (Cr. 3: $b = 1.59, t(254) = 6.01, p < .001, r = .35$); L3 imposed a significantly lower degree of defensive play than L4 (Cr. 4: $b = 1.24, t(254) = 2.55, p = .01, r = .16$).

In the non-linear adjustment, the defensive play imposed by NL1 and NL2 was significantly lower than NL3 and NL4 (Cr. 5: $b = -3.41, t(254) = -9.33, p < .001, r = .5$). I did not find significant differences between NL1 and NL2 (Cr. 6: $b = -0.42, t(254) = -1.03, p = .31, r = .06$), or between NL3 and NL4 (Cr. 7: $b = -0.46, t(254) = -0.79, p = .43, r = .05$).

I followed the same procedure to test the degree of restriction imposed on the more skilled players. I defined the planned comparisons shown in Figure 7.6. Note that this planned contrast analysis differs from previous one in the following contrasts: Cr. 5, Cr. 6 and Cr. 7.

The linear adjustment was significantly less restrictive than the non-linear adjustment

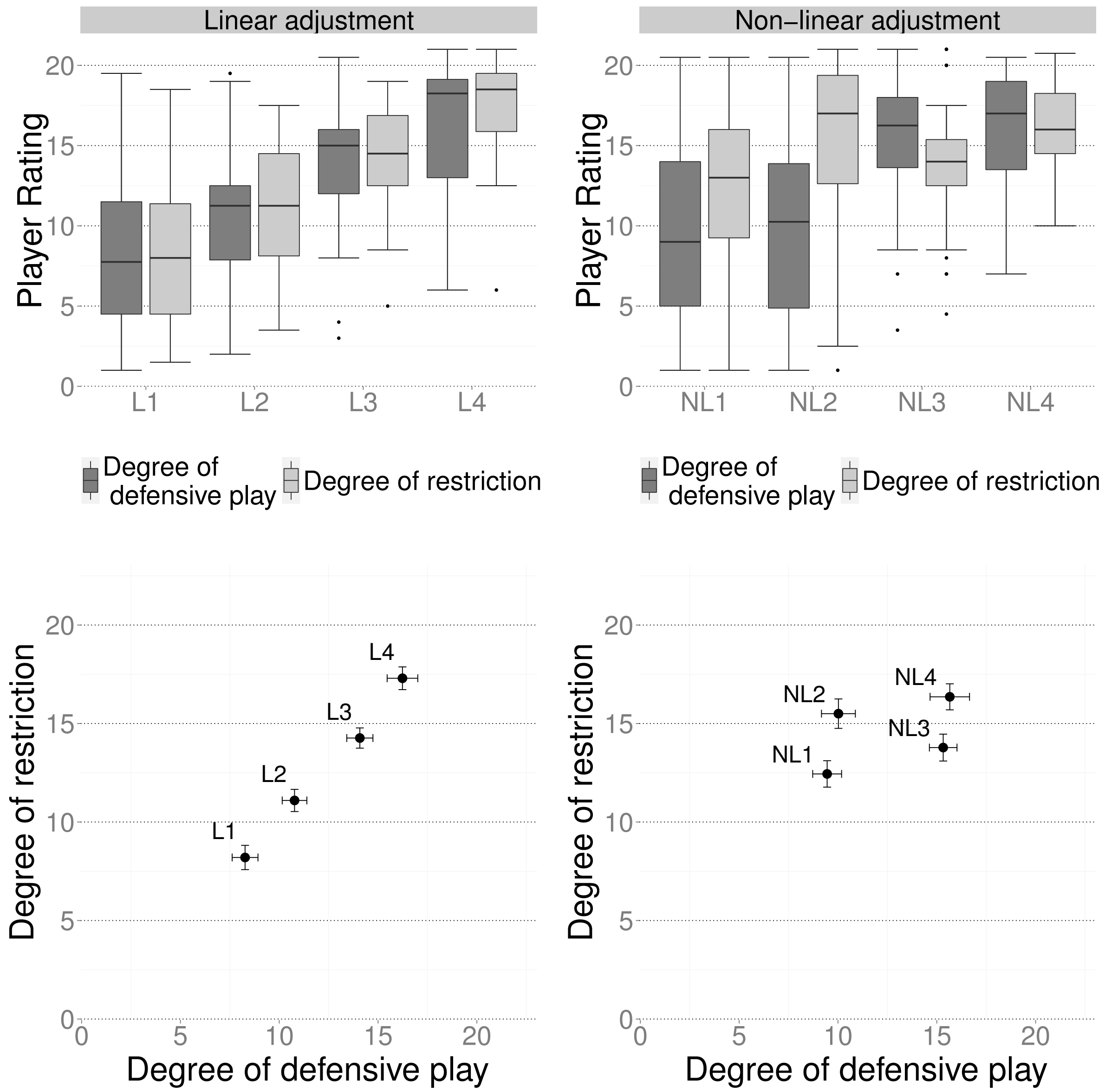

Figure 7.4: Case study 4. Results for the table configurations of the degree of defensive play imposed and degree of restriction imposed on the more skilled participants. Results are represented in boxplots of the linear table adjustment (top-left) and the non-linear table adjustment (top-right). The means and standard errors of the table configurations are represented in the two dimensional space in the linear adjustment (bottom-left) and the non-linear table adjustment (bottom-right). The range of players' ratings were [0:very low, 21: very high]

(Cr. 1: $b = -0.94, t(254) = -4.18, p < .001, r = .25$). L1 imposed a significantly lower degree of restriction than the other table configurations of the linear adjustment (Cr. 2:

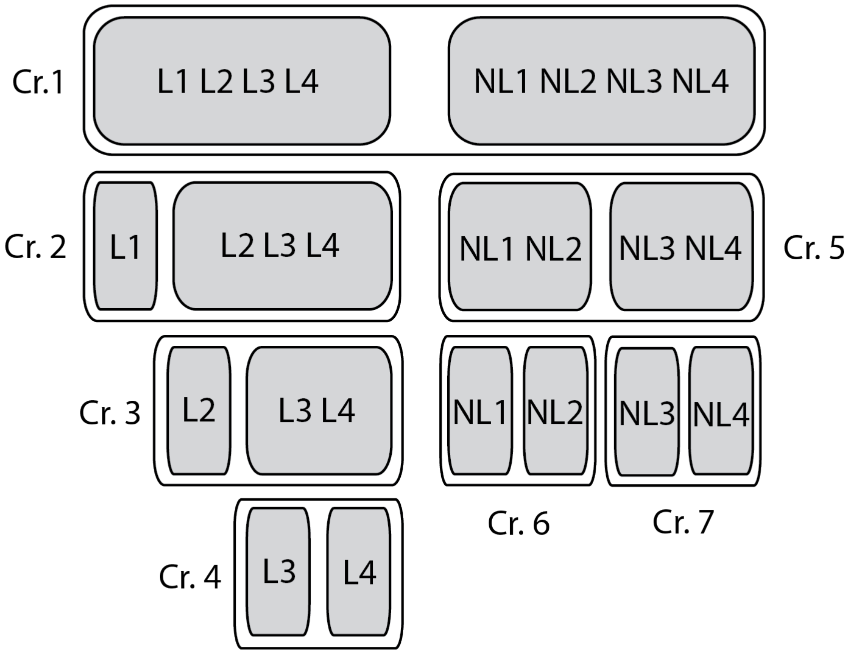

Figure 7.5: Case study 4. Defined planned contrasts to compare the defensive play imposed by the different table configurations in each table adjustment, for example the first contrast (Cr. 1) compares the four linear configurations against the four non-linear configurations, and the second contrast (Cr. 2) checks whether the configuration L1 imposed a different amount of defensive play than the other linear configurations (L2, L3 and L4)

$b = 1.58, t(254) = 9.84, p < .001, r = .53$); L2 imposed a significantly lower degree of restriction than L3 and L4 (Cr. 3: $b = 1.63, t(254) = 6.69, p < .001, r = .39$). Finally, L3 imposed a significantly lower degree of restriction than L4 (Cr. 4: $b = 1.61, t(254) = 3.59, p < .001, r = .22$).

In the non-linear adjustment, NL1 and NL3 imposed a significantly lower degree of restriction than NL2 and NL4 (Cr. 5: $b = -1.50, t(254) = -4.54, p < .001, r = .27$). NL3 was significantly more restrictive than NL1 (Cr. 6: $b = -0.89, t(254) = -2.12, p = .03, r = .13$); and NL2 was not significantly different from NL4 (Cr. 7: $b = -0.70, t(254) = -1.36, p = .18, r = .09$).

As the residuals of the MLM model were not normally distributed, I did a second analysis by removing two unusual ratings of a participant that caused the non-normality. The MLM results were similar to the previous analysis, with the exception that Cr. 6 became non-significant ($b = -0.76, t(252) = -1.84, p = .07, r = .12$). Therefore, I concluded that the degree of restriction between NL1 and NL3 was not significantly different.

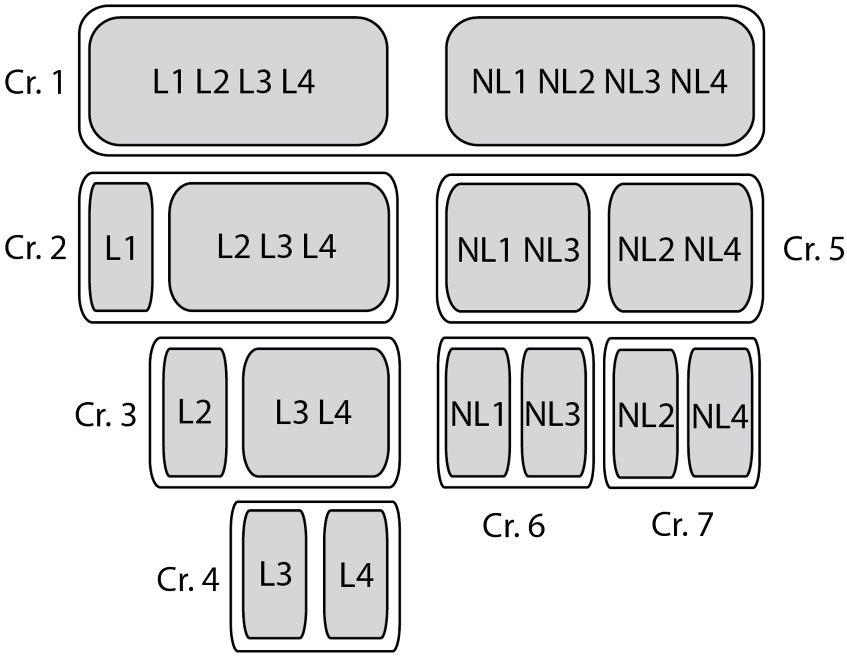

Figure 7.6: Case study 4. Defined planned contrasts to compare the restriction of the more skilled players' performance in the different table configurations in each table adjustment, for example, the first contrast (Cr. 1) compares the four linear configurations against the four non-linear configurations, and the second contrast (Cr. 2) checks whether the configuration L1 imposed a different degree of restriction than the other linear configurations (L2, L3 and L4)

This analysis confirmed the expected relationship between the table configurations, the defensive play induced by these table configurations, and the degree of restriction imposed on the more skilled players by these table configurations.

7.3.2 Players' performances

I studied players' performances in each table adjustment to better understand the player experience and player engagement. I report the number of times each table configuration was played and the percentage of points played in each table configuration, which show the frequency of times the more skilled participants played in each table configuration. Finally, I report the ball velocity results.

Table configurations played

The number of times each table configuration was played was: L1 (28/28), L2 (25/28), L3 (21/28), L4 (19/28), NL1 (28/28), NL2 (25/28), NL3 (19/28) and NL4 (11/28).

Points played in each table configuration

The percentage of points played in each table configuration is shown in Figure 7.7.

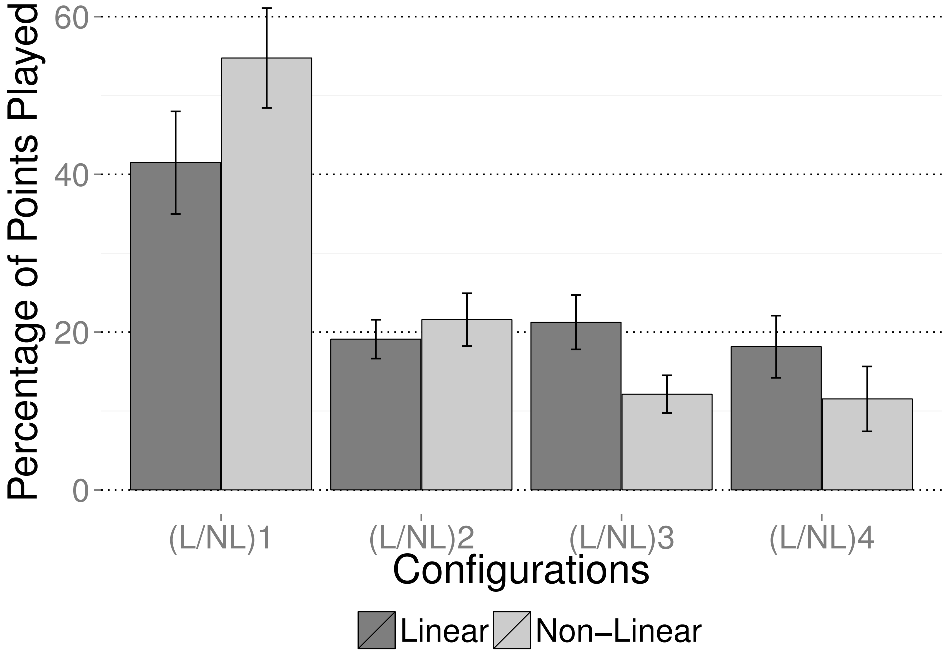

Figure 7.7: Case study 4. Percentage of points played in the different table configurations for both linear and non-linear table adjustments. The means and standard errors are shown

A repeated measures ANOVA was carried out with the eight table configurations of the two table adjustments as a within factor, and the percentage of points played in each table configuration as the dependent variable. The assumption of sphericity was violated and I adjusted the degrees of freedom using the Huynh-Feldt estimate (ϵ=0.42). There were differences between the percentage of points of the eight configurations, $F(2.94, 79.38) = 10.8, p < .01, \eta^2_G = 0.29$. The pair-wise comparisons with Bonferroni corrections showed that L1 did not differ significantly from NL1 (p=0.87). However, the percentage of points played in L1 and NL1 differed significantly from all the other table configurations (all p<.05). No other significant differences were found. Although in both table adjustments participants played more points in the first table configuration, they also experienced the other table configurations.

Ball velocity

For ball velocity results, I report results about its magnitude. The average ball velocity in both table adjustments and in the no-adjustment condition is shown in Figure 7.8. I defined planned contrasts to compare more skilled vs. less skilled participants (Contrasts (Cr.) 1); the no-adjustment condition against the aggregate of linear and non-linear adjustments for the more skilled participants (Cr. 2); linear against non-linear adjustments for the more skilled participants (Cr. 3); the no-adjustment condition against the aggregate of linear and non-linear adjustments for the less skilled participants (Cr. 4); and linear vs. non-linear adjustments for the less skilled participants (Cr. 5).

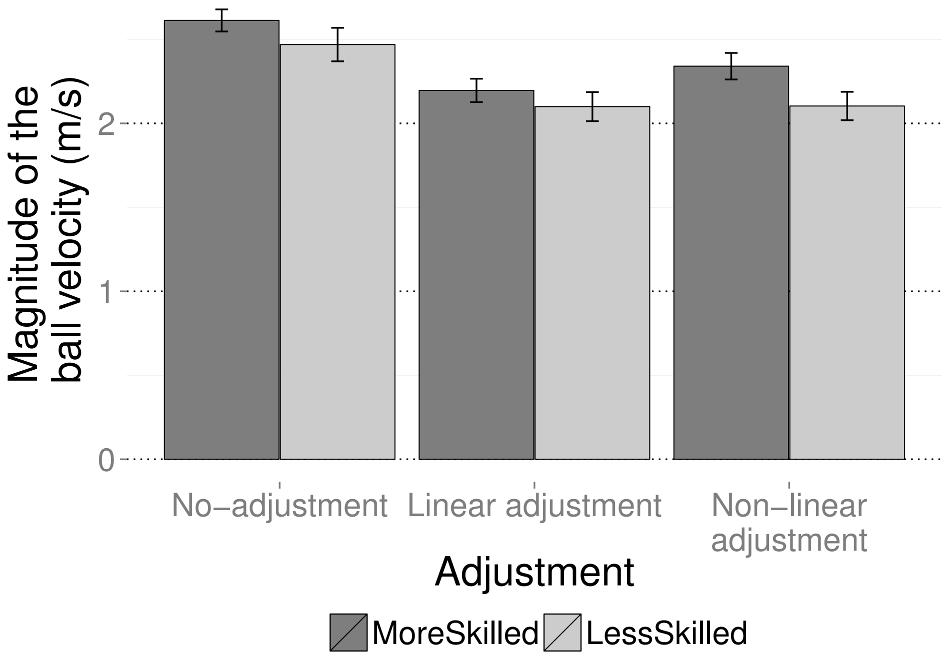

Figure 7.8: Case study 4. The magnitude of the ball velocity in each of the no-adjustment condition, linear adjustment and non-linear adjustment. The means and the standard errors are shown

The magnitude of the ball velocity of the more skilled participants (M=2.38, SD=0.4) was significantly higher than for the less skilled participants (M=2.22, SD=0.50), Cr. 1: $b = 0.09, t(22) = 3.07, p = .006, r = .55$. For the more skilled participants, the ball velocity was significantly higher in the no-adjustment condition (M=2.61, SD=0.34) than with both table adjustments (M=2.27, SD=0.38, Cr. 2: $b = 0.11, t(98) = 5.92, p < .001, r = .51$. The ball velocity in the non-linear adjustment (M=2.34, SD=0.4) was significantly higher than in the linear adjustment (M=2.19, SD=0.36, Cr. 3: $b = 0.07, t(98) = 2.15, p = .03, r = .21$. This shows the more skilled participants played more aggressively in the non-linear table adjustment than the linear table adjustment.

For the less skilled participants, the ball velocity was significantly higher in the no-adjustment condition (M=2.47, SD=0.50) than with both table adjustments (M=2.10, SD=0.42), Cr. 4: $b = 0.12, t(98) = 6.20, p < .001, r = .53$), but no significant differences were found between the linear adjustment (M=2.10, SD=0.43) and the non-linear adjustment (M=2.10, SD=0.42), Cr. 5: $b = -0.002, t(98) = -0.05, p = .96, r = .005$.

I also analysed the different table configurations for the linear table adjustment (Figure 7.9) and non-linear table adjustment (Figure 7.10).

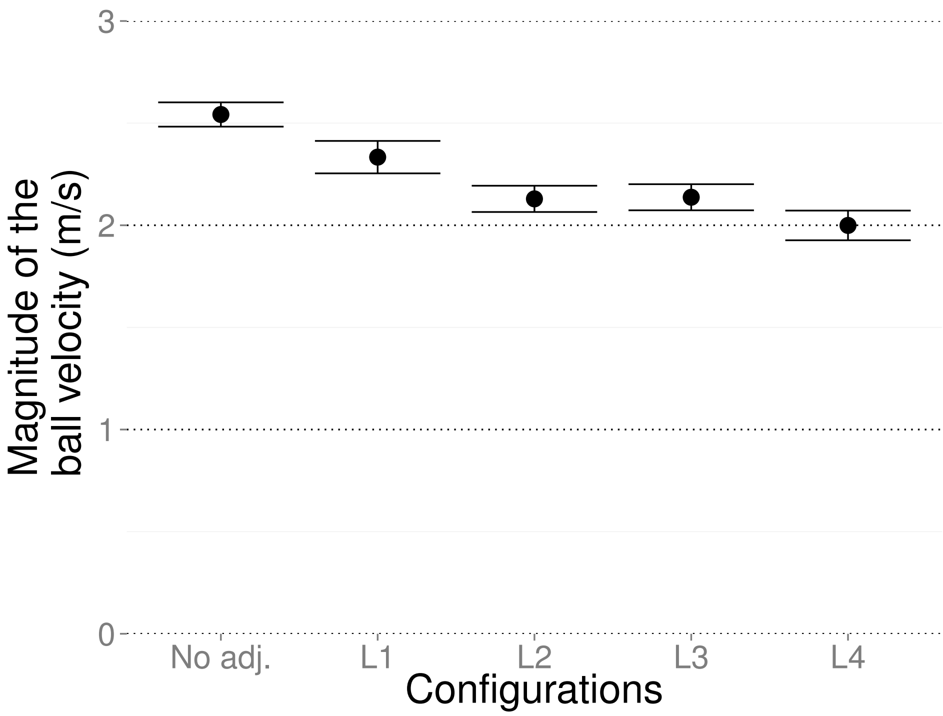

Figure 7.9: Case study 4. The magnitude of the ball velocity in the different linear table configurations (L1, L2, L3 and L4) and the no-adjustment condition (No adj.). The means and standard errors are shown

I defined planned contrasts to evaluate whether the magnitude of the ball velocity decreased as the playing surface area size became smaller and closer to the net. The ball velocity in the no-adjustment condition was significantly higher than in the linear adjustment ($b = 0.08, t(160) = 7.13, p < .001, r = .49$). L1 and L2 had significantly higher ball velocity than L3 and L4 ($b = -0.08, t(160) = -3.09, p = .002, r = .24$). L1 had significantly higher ball velocity than L2 ($b = 0.09, t(160) = 2.62, p = .001, r = .2$), and no significant differences were found between L3 and L4 ($b = 0.05, t(160) = 1.2, p = .23, r = .09$).

For the non-linear table adjustment I defined the planned contrasts to compare the ball velocity between the table configurations that induced defensive play (NL3 and NL4) against the table configuration that induced a less defensive play (NL1 and NL2). Then I compared the effects in the ball velocity of different degree of restriction within the table configurations that induced defensive play (NL3 against NL4). Similarly, I compared NL1 against NL2. The ball velocity in the no-adjustment condition was significantly higher than the non-linear adjustment ($b = 0.07, t(143) = 4.47, p < .001, r = .35$). The ball velocity in NL1 and NL2 was significantly higher than NL3 and NL4 ($b = 0.26, t(143) = 6.17, p < .001, r = .46$). No significant differences were found between NL1 and NL2 ($b = -0.05, t(143) = -1.05, p = .30, r = .09$), or between NL3 and NL4 ($b = -0.08, t(143) = -1.18, p = .24, r = .10$).

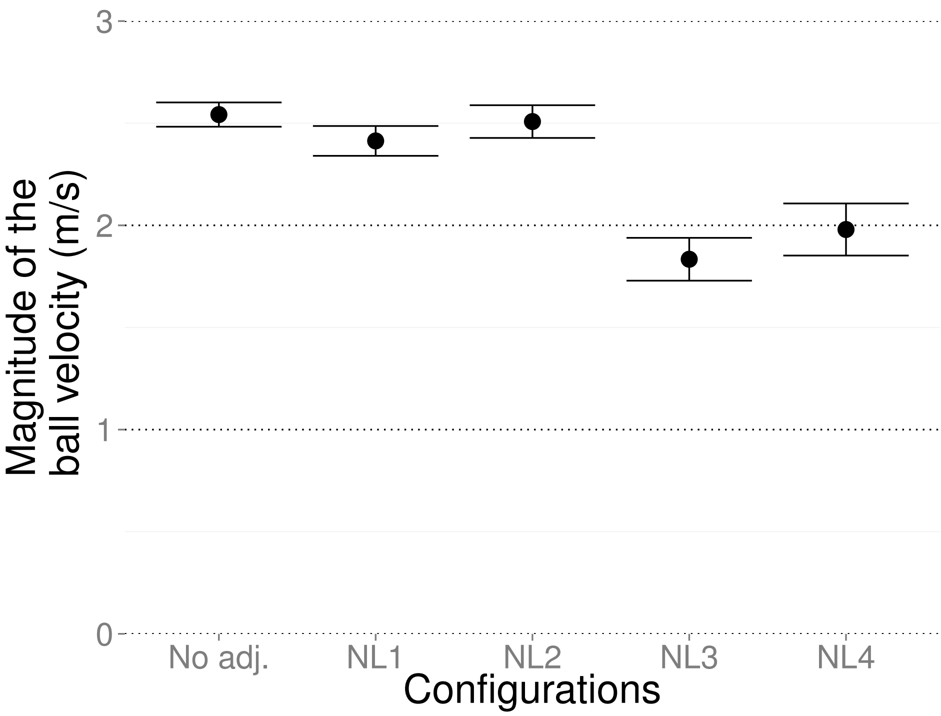

Figure 7.10: Case study 4. The magnitude of the ball velocity in the different non-linear table configurations (NL1, NL2, NL3 and NL4) and the no-adjustment condition (No adj.). The means and standard errors are shown

The ball velocity analysis of the different table configurations in both table adjustments is in line and supports the participants' subjective ratings analysis of defensive play induced in each of the table configurations (see 7.3.1). The Spearman correlation between ball velocity and the subjective perception of defensive play (-0.2) was significantly different from zero ($p < .001$).

7.3.3 Game balancing

Game balancing in each table configuration

In the linear game I evaluated the percentage of points won by the more skilled participants in each table configuration (see Figure 7.11).

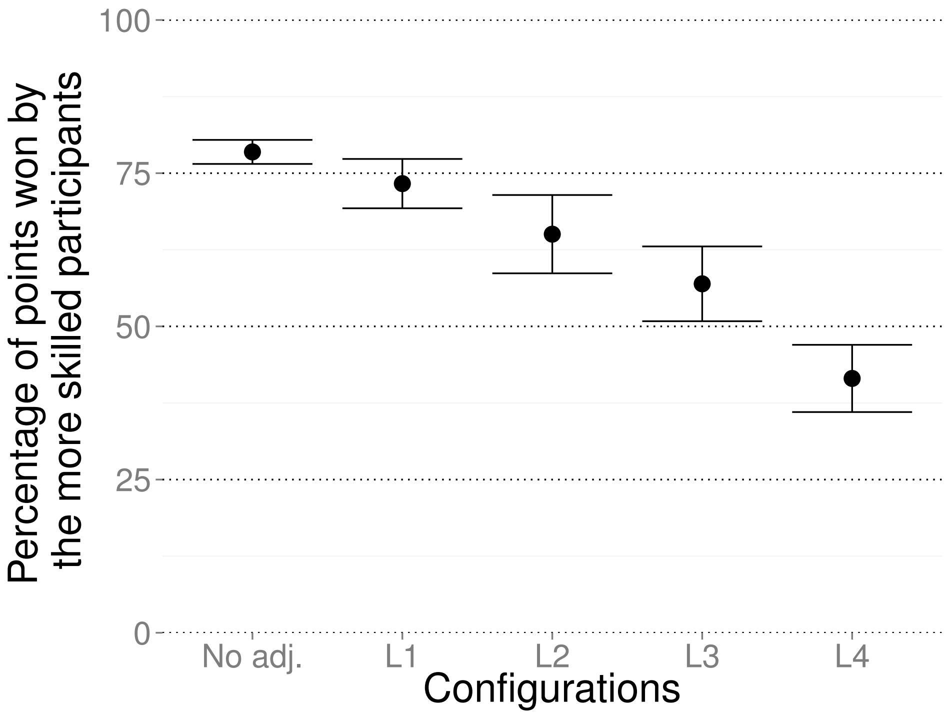

Figure 7.11: Case study 4. Percentage of points won by the more skilled participants in the different linear table configurations and in the no-adjustment condition. The means and standard errors are shown

I built a MLM model with the different table configurations of the linear table adjustment and the no-adjustment condition as predictors of the percentage of points won by the more skilled participants. The percentage was significantly higher in the no-adjustment condition than in the linear adjustment ($b = 4.6, t(81) = 5.93, p < .001, r = .55$). The percentage of L1 and L2 was significantly higher than in L3 and L4, $b = -12.94, t(81) = -6.73, p < .001, r = .60$. Finally the percentage in L1 was significantly higher than L2 ($4.9, t(81) = 2.00, p = .049, r = .21$), and the percentage in L3 was significantly higher than in L4 ($b = 9.0, t(81) = 3.16, p = .002, r = .33$).

An analysis of the non-linear table adjustment was then performed (see Figure 7.12). The percentage in the no-adjustment condition was significantly higher than in the non-linear adjustment ($b = 6.75, t(72) = 7.9, p < .001, r = .68$). The percentage was higher in NL1 and NL2 than in NL3 and NL4, $b = 9.83, t(72) = -4.23, p < .001, r = .44$. The percentage was higher in NL1 than in NL2 ($b = -7.26, t(72) = -2.78, p = .007, r = .31$), and was higher in NL3 than in NL4 ($b = 7.59, t(72) = 2.06, p = .04, r = .24$).

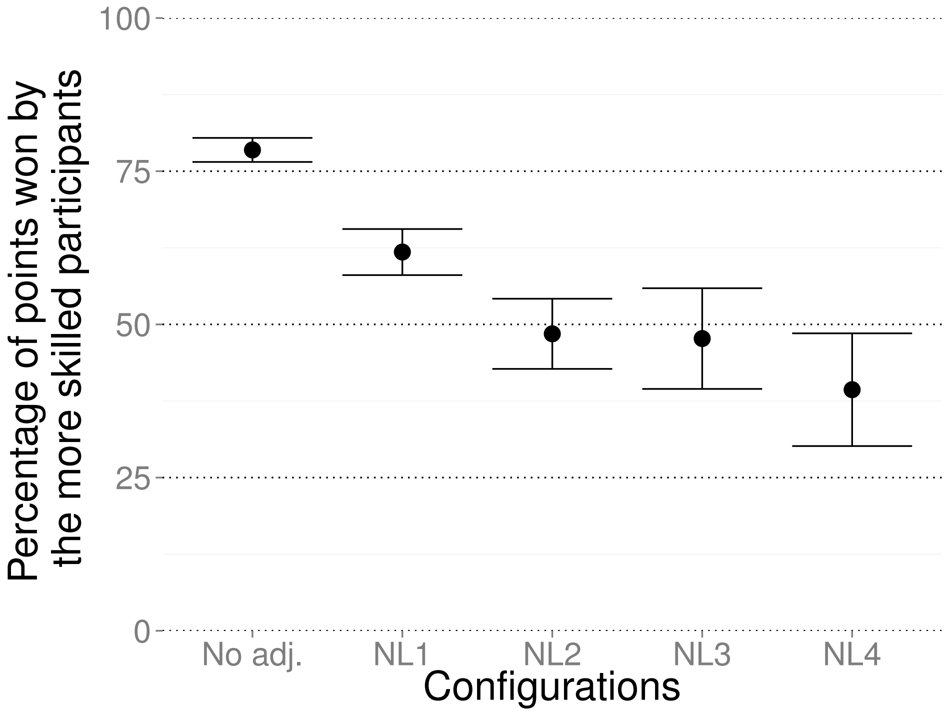

Figure 7.12: Case study 4. Percentage of points won by the more skilled participants in the different non-linear table configurations and in the no-adjustment condition. The means and standard errors are shown

Having analysed the data in both table adjustments and in the different table configurations within each table adjustment, I now assess how the study results contribute to answer the research questions.

RQ1: How does the style of play imposed on the more skilled players affect

game balancing? When the table configurations increased the amount of defensive play imposed on the more skilled players, the win probability of the more skilled players significantly decreased. The Spearman correlation coefficient between the defensive play and the percentage of wins of the more skilled participants, in the eight table configurations of the linear and non-linear table adjustments, was high (–0.48) and it was significantly different from zero ($p < .001$).

RQ3: How does the amount of challenge of a restriction imposed on the more skilled players affect game balancing? When the table configurations increased the amount of challenge owing to the restriction imposed, the win probability of the more skilled players significantly decreased. The Spearman correlation coefficient between the amount of challenge of the restriction and the percentage of wins of the more skilled participants, in the eight table configurations of the linear and non-linear table adjustments, was high (–0.45) and also significant differently from zero ($p < .001$).

I should note that taking into account all eight table configurations, the Spearman correlation coefficient reported a high correlation between the defensive play imposed, and the amount of challenge of the restriction imposed (0.68), and this correlation was significantly different from zero ($p < .001$). This was expected, taking into account the design of the linear table adjustment. However, the analysis of the percentage of points won by the more skilled participants in the non-linear table adjustment indicates that both the defensive play induced, and the amount of challenge imposed on the more skilled participants in playing with the restriction, affected the percentage of points won by the more skilled participants.

RQ6: Regarding game balancing, is there an interaction effect between the style of play and the amount of challenge of a restriction imposed on the more skilled players? The study results did not show any interaction effect. In the non-linear adjustment, the increase of the amount of restriction on the more skilled players reduced the win probability of the more skilled participants both when they had to play defensively (from NL3 to NL4) and when they could play less defensively (from NL1 to NL2).

Game balancing in each table adjustment

I report the results regarding the score difference, win/lose ratio and average hits per point in each table adjustment. The average hit per point can be important to take into account as a measurement of balancing non-parallel games because it can indicate whether a game adjustment moderates the influence of a player's action on the other player's performance.

Score difference: The difference in score in each table adjustment and in the no-adjustment condition is shown in Figure 7.13. The Friedman test showed there were significant differences between the difference of score (in absolute values) between the no-adjustment condition (M=14.80, SD=3.76), linear table adjustment (M=6.12, SD=4.09) and non-linear table adjustment (M=5.42, SD=3.94), $\chi^2(2) = 38.48, p < .001$. Post-hoc tests with Bonferroni correction showed the no-adjustment condition significantly differed from the linear and non-linear table adjustments (in both $p < .001$). No differences were found between the linear and non-linear table adjustments ($p = 1.0$).

Win/lose ratio: In the no-adjustment condition, the more skilled participant won all games (26/26), in the linear table adjustment the more skilled participants won 21/26 of the games and in the non-linear table adjustment the more skilled participants won 14/26 of the games. The Fisher's exact test indicated that the adjustments (linear, non-linear and no-adjustment) had a significant influence on the number of matches won by the more skilled participants ($p < .001$).

Average hits per point: The average number of hits per point is shown in Figure 7.14. The Friedman test showed significant differences between the no-adjustment condition, linear adjustment and non-linear adjustment ($\chi^2(2) = 38.67, p < .001$). Post-hoc tests with Bonferroni correction showed that the number of hits per point in the linear adjustment (M=4.22, SD=2.34) was greater than both the no-adjustment condition (M=3.36, SD=1.37), $p < .001$, and the non-linear adjustment (M=2.91, SD=1.52), $p < .001$. The number of hits per point in the no-adjustment condition was greater than in the non-linear adjustment ($p < .001$).

Having analysed the data regarding game balancing in each table adjustment, I now assess how the study results contribute to answer the research question.

RQ7: How should dynamic adjustments based on the restriction of players' performance be designed to improve game balancing? The study results show that the linear adjustment was the adjustment that facilitated better game balancing. It balanced the game score as in the non-linear adjustment and also rewarded the more skilled participants more (higher win/lose ratio for the more skilled participants). Rewarding the more skilled players can be important for game balancing [1, p. 324]. In addition, the linear adjustment provided a greater average number of hits per point

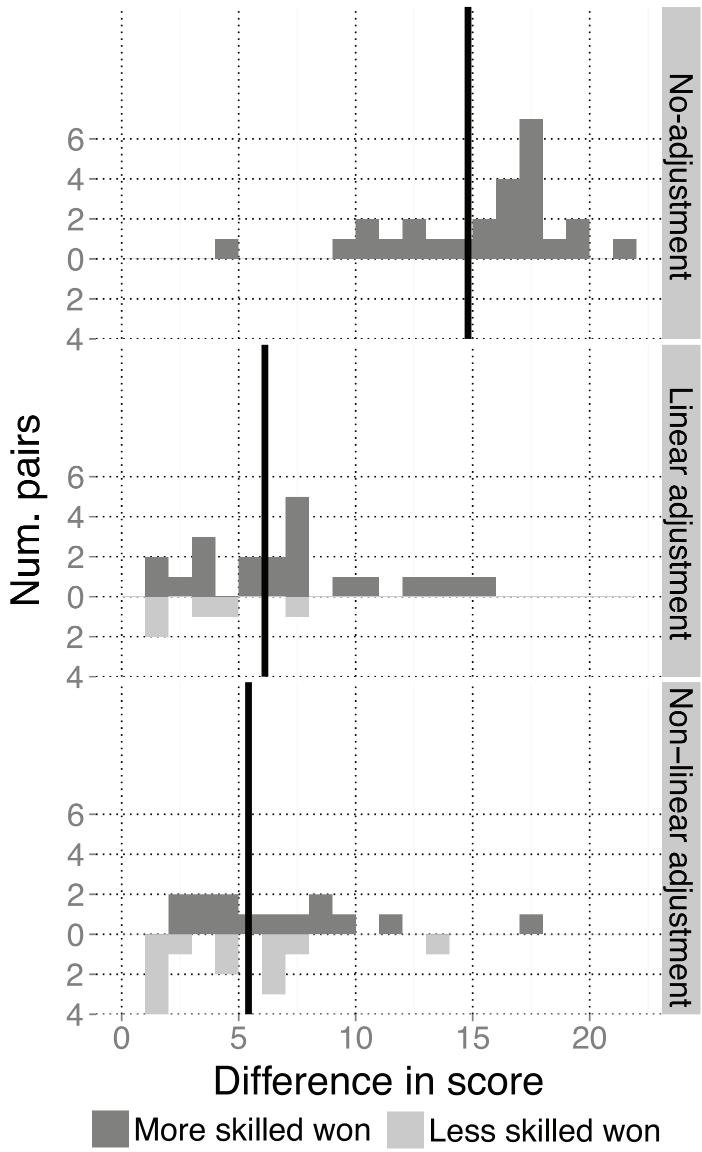

Figure 7.13: Case study 4. Histogram showing the difference in score of all pairs of participants in the no-adjustment condition, linear adjustment and non-linear adjustment. The number of wins of the more skilled and the less skilled participants are shown. The vertical black line is the mean of the distribution in each of the table adjustment and no-adjustment conditions

than the no-adjustment condition and non-linear adjustment, which lead to longer game rallies. This indicates that the linear adjustment might be more suitable to moderate the influence of a player's actions on the other player's performance.

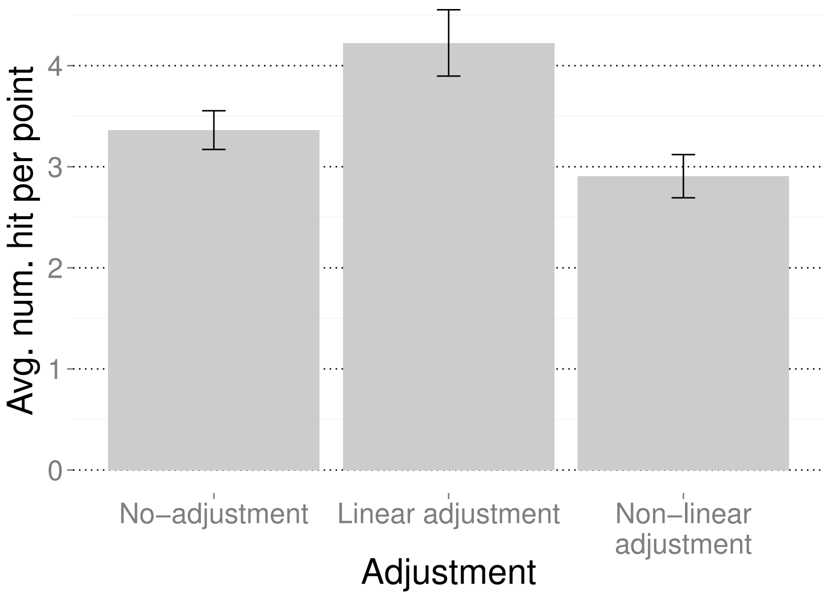

Figure 7.14: Case study 4. Average number of hits per point (per pair). The mean and standard errors are shown

7.3.4 Player engagement

I evaluated player engagement of the linear and non-linear games, and also assessed preferred individual table configurations for each table adjustment.

Player engagement in each table configuration

For the linear table adjustment, I was mainly interested to know if the ranking followed any pattern, such as "*the bigger the table, the more preferable*". As I evaluated tendencies, I discarded the rankings of those participants who played in fewer than three table configurations (17 participants). I report the results of 34 participants. Eleven participants preferred playing with a bigger surface area, 12 preferred playing with a smaller surface area, and 5 preferred playing with a smaller surface area but ranked the smallest surface area as the worst configuration.

The more skilled participants' reasons for preferring a bigger playing surface area were the game mistakes (e.g. saying "*I prefer the bigger table because I can be more engaged, I do not have to worry much about the strokes I miss*"); the gameplay, such as the type of strokes the players could perform (e.g. saying "*the bigger the better, because*

I can do whatever I want"); and the style of play (e.g. saying "*the smaller the table the less engaging, because it forces me to be defensive*"). The less skilled participants who preferred the configurations where the more skilled participants played in the bigger playing surface area, chose these configurations as the most preferred because of the challenge they provided.

The more skilled participants' reasons for preferring a smaller table were because of the challenge it provided (e.g. saying "*the smaller the more engaging, because it is more difficult*"). The less skilled participants who preferred a smaller playing surface area considered the table configurations helped with leveling the skills and the score (e.g. saying "*the smaller, the more difficulties for the opponent player. This levels the score and we can be more engaged in the game*").

For the non-linear adjustment, I investigated (i) whether participants preferred the configurations that induced a more defensive or less defensive style of play; (ii) whether participants preferred more restrictive or less restrictive table configurations when the table configurations induced a defensive style of play (NL3 and NL4), and when the table configurations induced a more attacking style of play (NL1 and NL2).

Defensive vs. non-defensive play: I report results of 34 participants who experienced at least the third table configuration. Of the 17 more skilled participants, 14 preferred the table configurations that induced a less defensive style of play because of the gameplay, such as the type and variety of strokes they could perform. Of the 17 less skilled participants, 9 preferred the table configurations that induced a more defensive style of play because of the gameplay and the challenge perceived (e.g. saying "*the third configuration is the best because it slowed him down, made it easier to turn shots back, lead to longer rallies and better engagement*").

More restriction vs. less restriction when the more skilled participants played more defensively (in NL3 and NL4 table configurations): I report results of 19 participants, those participants that played the four table configurations. Of the 10 more skilled participants, 7 selected the less restrictive configurations because of the greater stroke options available (e.g. saying "*the last configuration I did not like because I could only play in the middle. The best configuration is the third one*"). In contrast, the more restrictive configuration was the most preferred by 5 of the 9 less skilled participants.

More restriction vs. less restriction when the more skilled participants played less defensively (in NL1 and NL2 table configurations): I report results of 46 participants who played at least the two first game configurations (NL1 and NL2).

Of the 23 more skilled participants, 18 selected NL1 as the most preferred because the greater variety of strokes it facilitated (e.g. saying "*I prefer the option that gives me more attacking options*"). Similarly 15/23 of the less skilled participants preferred NL1 because they considered NL2 induced too many game mistakes in their opponents, which they did not enjoy, and because they had to defend all the time from the same strokes.

RQ2: How does the style of play imposed on the more skilled players affect player engagement? The degree of defensive play influenced player engagement. The more skilled players did not like to play with a defensive style of play. However, the less skilled players reported that the defensive style of play helped level the participants' skills, provided longer rallies and enhancing player engagement.

RQ4: How does the amount of challenge of a restriction imposed on the more skilled players affect player engagement? An increase of the restriction on the players' performance influenced player engagement. For most of the skilled participants, this increase negatively affected player engagement because the increase of game mistakes and the limitation of the variety of strokes that could be successfully performed. For the less skilled participants, although an increase of restriction on their opponents helped them score more points, the opponents' mistakes were not perceived as enjoyable.

RQ5: Regarding player engagement, is there an interaction effect between the style of play and the amount of challenge of a restriction imposed on the more skilled players? For the more skilled participants, there was no interaction effect. The less restrictive configuration was the most preferred when the more skilled participants played more defensively (NL3 and NL4) and when the more skilled participants played less defensively (NL1 and NL2). However, the less skilled participants preferred the less restrictive configuration when it induced an aggressive style of play (NL1 more preferred than NL2), and the more restrictive configuration when it induced a defensive style of play (NL4 more preferred than NL3). For the less skilled participants, the feeling was that restricting the more skilled participants was good because that meant to score more points, but NL2 induced too many game point mistakes.

Player engagement in each table adjustment

The Wilcoxon test showed that the engagement scores (see Figure 7.15) of the linear adjustment (M=3.79, SD=0.54) were higher than the scores of the non-linear adjustment (M=3.59, SD=0.54), $W = 827.5, p = .002$.

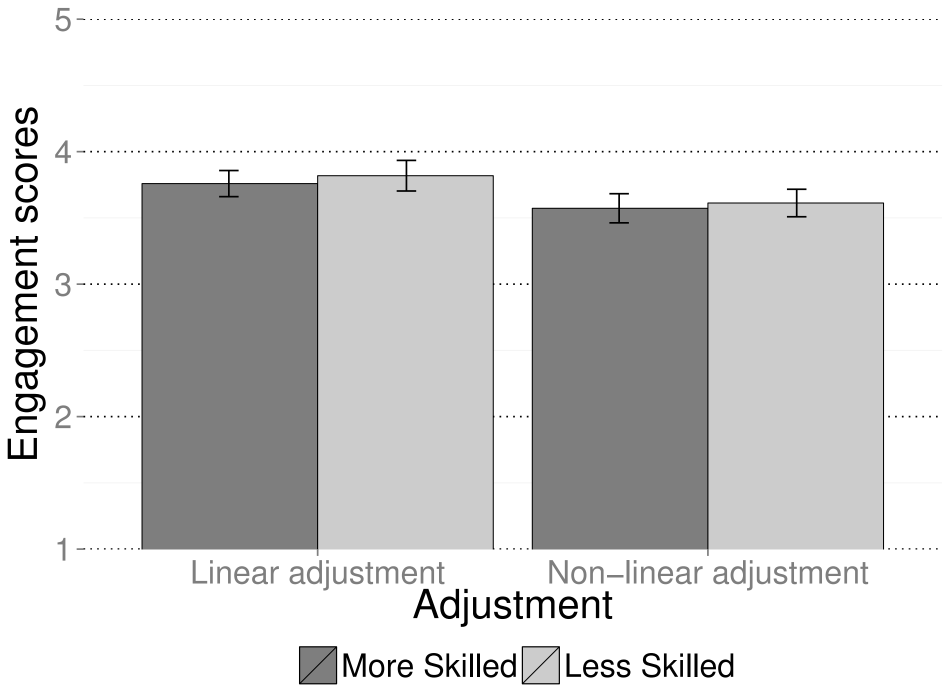

Figure 7.15: Case study 4. Player engagement scores in the linear and non-linear adjustments for the more skilled participants and the less skilled participants

Figure 7.16 shows that while more less skilled participants preferred the linear adjustment (30) to the non-linear adjustment (16); the number of more skilled participants preferring the non-linear adjustment (24) was higher than the number preferring the linear adjustment (16). The Fisher exact test showed a significant relationship between the adjustment selected and players' skill status ($p = .007$).

To understand the engagement scores and the player experience better I analyzed the semi-structured interviews.

More skilled participants playing in the linear adjustment: The most frequently reported engaging aspects of this game for the 26 more skilled participants were the gameplay, which referred to the length of points and the perception of a social and less competitive game (reported by 7 participants), and the ability to level the skills (3 participants). Four participants reported a downside of this adjustment being the defensive style of play induced.

More skilled participants playing the non-linear adjustment: The most frequently reported engaging aspects were the challenges provided (reported by 10 partic-

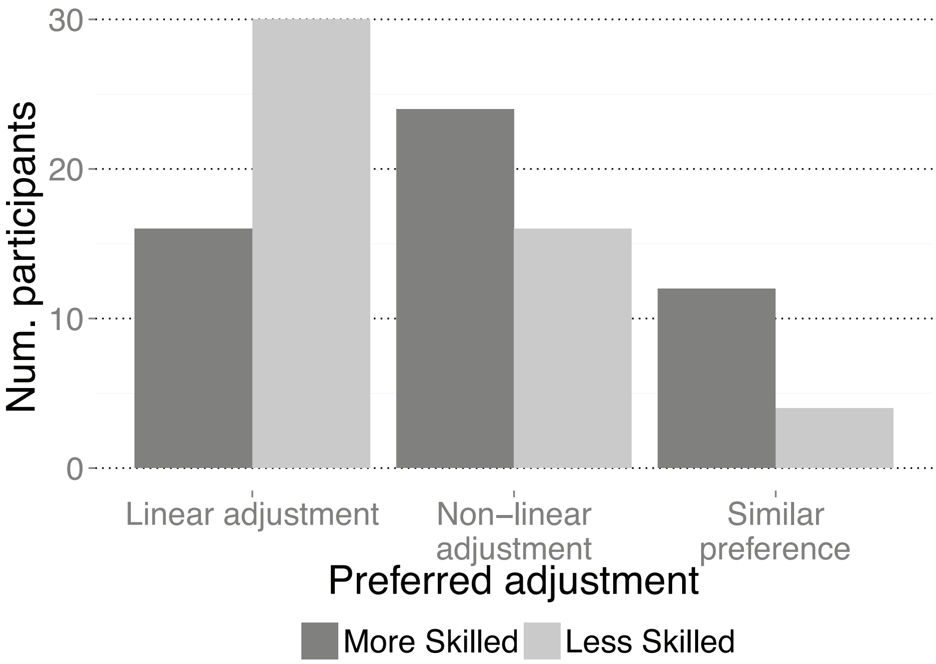

Figure 7.16: Case study 4. Number of participants who selected the linear adjustment and non-linear adjustment as the most preferred table adjustment in terms of player engagement. Participants who did not have any preference are also shown ("none")

ipants), the gameplay, such as the variety and types of strokes the participants could perform, such as the smash (10 participants), and the ability to use the game as an activity to train strokes (3 participants). The downsides reported were the perception of too much challenge and the difficulty of adaptation to the table configurations, which increased game mistakes (5 participants), and lead to shorter game rallies (1 participant).

Less skilled participants playing in the linear adjustment: The most frequently reported engaging aspects were the gameplay provided, such as longer game rallies (10 participants) and the ability to level players' skills (4 participants).

Less skilled participants playing the non-linear adjustment: The most frequently reported engaging aspects were the gameplay, such as shots performed by the opponents' player (3 participants), and the challenge facilitated (3 participants). There were more downsides reported for this adjustment, such as the perception of too much challenge (6 participants), and the type of gameplay encouraged (6 participants) and the difficulty in countering the opponent player (e.g. saying "*when he puts the ball on the* *green square he won, otherwise I won*").

RQ8: How should dynamics adjustments based on a restriction of players' performance be designed to enhance player engagement? The linear adjustment enhanced player engagement more than the non-linear adjustment. Both table adjustments had their strengths. The non-linear adjustment provided an increased challenge to participants and the ability to practise long strokes that were difficult to counter. This was engaging for the more skilled participants. However, the non-linear adjustment facilitated many game mistakes and often the less skilled participants were unable to counter the skilled participants' play. In contrast, the linear game leveled players' skills more effectively and increased the length of game rallies (see 7.3.3).

7.4 Discussion

This study provided an enhanced understanding about how the previously identified ways of restricting players' performances can contribute to game balancing (see study in chapter 6). First, through the degree of challenge imposed by a restriction (e.g. altering the playing surface area size), and second through the degree of assistance given to the less skilled players in countering the performance of the more skilled players through the modulation of the more skilled players' style of play (e.g. altering the playing surface area location to induce different styles of play). The results showed a relationship between the restriction on players' performance and player engagement that can assist in designing engaging and balancing game adjustments for non-parallel exertion games (see Figure 7.17).

7.4.1 Understanding the relationship between the restriction on a player's performance and player engagement to design engaging balanced game adjustments

The restriction on players' performance is described based on the degree of challenge imposed on the more skilled players, and the degree of assistance given to the less skilled players through modulating players' style of play. The relationship shown in Figure 7.17 shows that to enhance player engagement for both players (more skilled and less skilled), a balance is necessary between the degree of challenge imposed on the more skilled players and the degree of assistance given to the less skilled players through modulating the more skilled players' play.

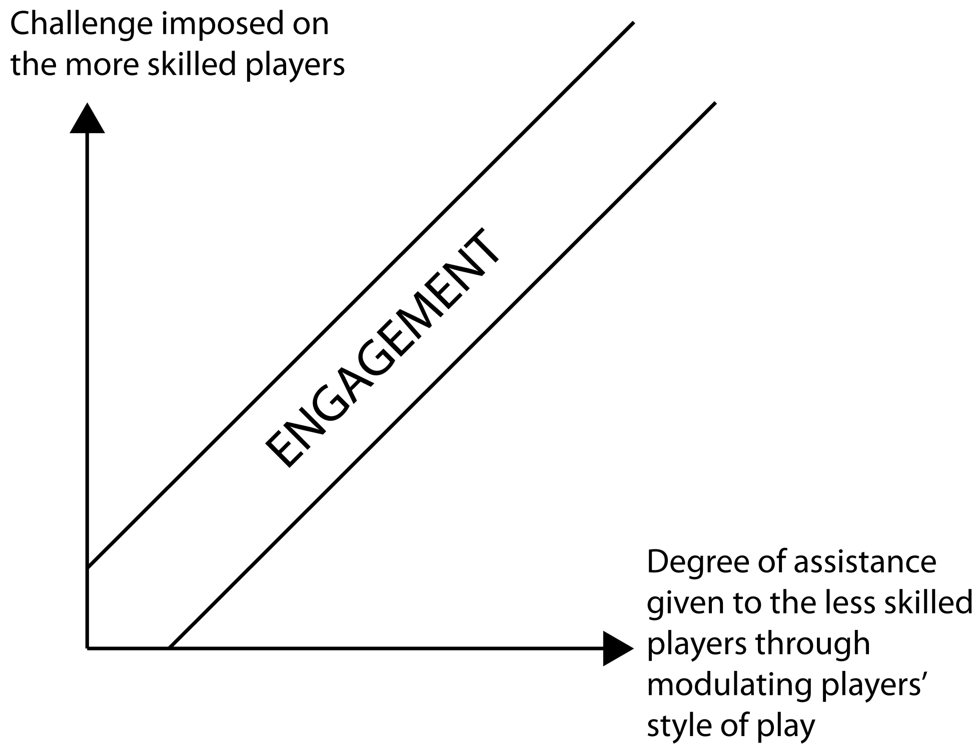

Figure 7.17: The relationship between the restriction on players' performance and player engagement to design engaging and balancing game adjustments. Players' performance is described based on the degree of assistance given to the less skilled players in countering the more skilled players, and the degree of challenge imposed on the more skilled players

The relationship between the restriction on players' performance and game balancing

The study results showed that both the assistance given to the less skilled players through the amount of defensive play induced on the more skilled players, and the increase in the degree of challenge owing to the restriction in place, affected the percentage of points won by the more skilled participants (see RQ1 and RQ3 in 7.3.3). Therefore, to balance a game, a game designer can use the additive effect of both ways of restricting players' performance for game balancing without the need to implement overly restrictive adjustments, or to modulate the style of play too much when trying to assist the weaker players. The study results showed that this approach can provide higher levels of engagement than balancing by just imposing a high degree of challenge (and inducing many mistakes), or by just inducing a high level of defensive play.

The relationship between the restriction on players' performance and player engagement

The study results indicate that a balance is necessary between the assistance given to the less skilled players through the amount of defensive play induced on the more skilled players, and the increase in the degree of challenge owing to the restriction in place, for enhancing player engagement for both players. Modulating the more skilled players' play to assist the less skilled players can be necessary to overcome their skill difference (see 7.3.4). However, altering the style of play as a means to assist the less skilled players might result in encouraging the use of a less engaging range of actions, such as players' strokes, for the more skilled players (see 7.3.4). This is supported by the study results in chapter 6. Similarly, increasing the degree of restriction can be useful to induce game mistakes and balance the game score (see 7.3.4 and 7.3.3). The downsides of restricting players' performance include making the game more prone to mistakes, which can reduce players' interest on the game and impact negatively on player experience. This is supported by prior work [3][49]. Another downside of restricting players' performance is that it can reduce the range of actions the stronger player can perform, which can influence player engagement (see ¡!–7.3.4). Prior work already identified the importance of avoiding overly restrictive adjustments and encouraging free play [24], and providing players with the feeling of autonomy [34].

The relationship between the restriction on players' performance and game design

The design of the linear adjustment and non-linear adjustment (see 7.2.4) and the proposed relationship (see Figure 7.17), suggest that the linear adjustment might support more player engagement than the non-linear table adjustment. The study results of engagement are in line with this since I found higher engagement scores in the linear adjustment than in the non-linear adjustment.

The linear adjustment was not as restrictive as the non-linear adjustment, see 7.3.1. Furthermore, it increased the amount of restriction progressively. This prevented the occurrence of as many mistakes as in the non-linear adjustment, and facilitated longer game rallies (see 7.3.3). In addition, the linear table adjustment progressively increased the degree of assistance to the less skilled players by altering the more skilled players' play progressively towards a more defensive style. Finally, the linear adjustment was perceived as more helpful for leveling players' skills.

7.4.2 Generalization of the results and limitations

The design of two table adjustments with different configurations was useful to evaluate different table configurations with different player restrictions. However, I could not evaluate all participants in all table configurations because the number of configurations each pair of participants played depended on the score difference between them during each table adjustment played. Also, I decided to evaluate the table configurations using the participants' rankings on how much they felt engaged. I also used semi-structured interviews to discuss and assess the reason for these rankings and learn more about their experience. Although this evaluation method can be a limitation as I did not use the engagement questionnaire to evaluate the table configurations, I felt that the approach used was better to assess the player experience and player engagement for each table configuration individually. I would not have been able to control how much the overall experience of playing with the table adjustment would have influenced the engagement scores of each table configuration individually.

The limited number of participants prevented an effective study being carried out to investigate how the size of the difference in skill level influenced the results, and how the found relationship (see Figure 7.17) could be adapted to different sizes of skill level differences.

This study also has the limitations of the study reported in chapter 4 (see 4.4.3): the assessment of the participants' skills using a pre-questionnaire, and the limited number of participants preventing an analysis of whether (and how) the motivation of the participants to practise physical activity influenced the engagement scores.

Finally, I used a statistical test to assess mismatched participants (see 7.2.3), I note that the test has limitations in detecting mismatched participants, when the distribution has a great standard deviation. In this study, I concluded that all pairs of participants were well matched observing that the distribution of the final score difference between participants in the no-adjustment had reasonably small variance yet not having any outliers.

7.5 Conclusions

I conducted a study to investigate the impact on game balancing and player engagement of game adjustments that assist the less skilled players through moderating the style of play of the more skilled players, and that alter the degree of challenge faced by the more skilled players playing with a restriction.

The main contribution of this work is an understanding of the relationship between the restriction on players' performance and player engagement, which can help in balancing and enhancing player engagement in non-parallel games such as traditional sports. This relationship was derived from the analysis of player engagement and player experience of players playing table tennis in a set of modified table configurations.

The results of this study highlight the importance of understanding the interrelationship between game adjustments, game balancing and player engagement, and also provide insight into how to take this interrelationship into account in order to effectively balance games and enhance player engagement in non-parallel exertion games, such as traditional sports like table tennis, squash or tennis.

In the next chapter I discuss the overall contribution of the research and suggest future research directions.

Chapter VIII

Discussion and Conclusion

In this chapter I discuss the findings and outline future research directions.

8.1 Contributions

During the course of this research the following contributions have been made:

- An understanding of game balancing differences between different game worlds such as traditional and digital physical games, and game design considerations therefrom (chapter 4).

- The provision of a set of game design strategies to understand: (i) how we could limit players' skills and still enhance player engagement; (ii) how we could use the explicitness of an adjustment as a resource for enhancing player engagement; (iii) how we could moderate the influence of one player's actions on another's performances to enhance player engagement in non-parallel games (chapter 5).

- An identification of two ways how a restriction of players' performances can help in balancing exertion games; (i) through modulating the style of play, and (ii) through altering the challenge imposed in playing with a restriction in place, as well as the provision of two game design strategies therefrom (chapter 6).

- An understanding of (i) the impact of inducing different styles of play, and imposing different degrees of challenge on the more skilled players on game balancing and player engagement, and (ii) the relationship between the restriction on players' performance and player engagement for designing engaging and balanced exertion games derived therefrom (chapter 7).

- An understanding of the interrelationship between game adjustments, game balancing and player engagement in exertion games (chapters 4-7).

- An understanding of how digital technology can support game adjustment design (chapters 5-7).

8.2 Summary of thesis experiments

Chapter 4 evaluated a performance adjustment (by asking the stronger player to play with the non-dominant hand) and a score adjustment in different game worlds: a traditional and a digital table tennis game. Game adjustments affected game balancing and player engagement differently in the two game worlds because of the level of skill required to play in each one. For example, playing with the non-dominant hand affected the traditional game more than the digital one because of the greater degree of accuracy required of the players' movements. Prior work identified the game controller as important to understand the way players are engaged with the game [16] [15]. This can explain why playing with the non-dominant hand affected player engagement differently in the different game worlds.

The game adjustments did not enhance player engagement in any of the game worlds. In the traditional table tennis game, players playing with the non-dominant hand reported lower engagement than in the no-adjustment condition because of the loss of the sense of control. This is in line with the claim of Part et al. [78] about the importance of providing intuitive game interactions to enhance player engagement. In the digital table tennis game, players playing with a score disadvantage of six points reported lower engagement than playing with the no-adjustment condition because of an unacceptable competitive advantage. In this condition, the adjustment overbalanced the game. Prior work already identified that overbalancing the game can cause disengagement [41]. Although these adjustments actually reduced player engagement, I identified areas for improvement. For example, in the traditional table tennis game it was necessary to have more control over the influence of game adjustments on players' performances.

Chapter 5 presented a study with bat and table (playing surface area) adjustments in the traditional table tennis game. These adjustments were evaluated statically and dynamically. They impacted players' performances in a more controllable way than in the previous study (in chapter 4), and enhanced player engagement compared to the no-adjustment condition. From the study results I defined a set of game strategies about how to enhance player engagement. In particular, I identified the benefits of dynamic adjustment in providing short-term goals to players and in enhancing players' sense of achievement. Prior work already showed the importance for game design of advancement and rewards [35], and in the provision of short-term goals [24] [78]. In this study I showed how we could use these aspects of game design to design engaging game balancing adjustments. Finally, in this study I found that altering the style of play of the more skilled players and the type of strokes players are induced to perform is important for enhancing player engagement when balancing non-parallel games. Similarly, prior work identified that different body movements can engage players differently [15]. I further investigated these findings in the case study reported in chapter 6.

Chapter 6 presented a study where I restricted the more skilled players' performances by adjusting the table (playing surface area location). One adjustment encouraged short strokes and a defensive style of play, which made the task of returning the ball easier for the weaker players. The other encouraged a more aggressive style of play from the more skilled players with long strokes, which were difficult to counter by the opponent players, but were harder to play accurately. I identified two ways the adjustment of players' performances can help in balancing the game. First it can alter the style of play of the more skilled players, which can influence how easy is for the opponents to return the ball. Second the restriction can alter the amount of challenge and encourage game mistakes. The more skilled players found the game more engaging when they were asked to perform strokes that were difficult for the opponent to counter. In contrast, the less skilled players were more engaged when their opponents played more defensively since this helped levelling players' skills better. This indicates that the modulation of the style of play can be beneficial, but care must be taken as modulation of the play can encourage a gameplay that is less engaging for the more skilled players.

Chapter 7 further investigated game balancing through modulating the style of play, and through altering the amount of challenge imposed on players' performances. In this study I designed two table adjustments with four table configurations each. Each table configuration imposed a different restriction on the more skilled players' performances by altering the playing surface area size and location. After assessing that altering the playing surface area size and location altered the style of play of the more skilled players and the degree of restriction imposed as expected, I investigated how each table adjustment and each individual table configuration affected game balancing and player engagement.

The study results support previous findings in game balancing. That is, it is important to assist the less skilled players, for example, by modulating the style of play of the more skilled players. However, it is also important to avoid modulating the play too much. The study results showed that changing the amount of challenge by imposing a restriction can help in game balancing, but it is important to avoid applying overly challenging game adjustments. The study results were used to derive an understanding of the relationship between the restriction on players' performances and player engagement that can help in designing engaging balancing adjustments.

The insight obtained from this relationship is supported by findings of this research and also by the findings of prior work. This increases the reliability of the findings and contributions. Prior work emphasised the importance of challenge in game design [21] [51] [56] [59] [60] [77] [89] [95], and how players are challenged, such as by inducing different body movements [15]. Also, prior work emphasises the importance of providing free play [24], and a sense of autonomy [34]. Finally, it is important that players have control over their actions to achieve the Flow experience [30]. The relationship between the restriction on players' performance and player engagement derived emphasises the importance of the amount of challenge imposed by a restriction, but discourages applying overly challenging restrictions as this can affect the number of game mistakes and the number of actions the players can perform, and can have a negative effect on player engagement. The proposed relationship also suggests the need to provide more control over the players' actions by altering the style of play of the stronger player to moderate this player's influence on the weakers' performances. Moreover, the proposed relationship also takes into account the way in which players are challenged, by avoiding modulating the style of play too much as a means of assisting the weaker players in countering the more skilled player's performance. The different findings of this thesis research and the relationship derived are supported by and build on prior work.

8.3 Game balancing factors

From this research different factors have been identified that can affect game balancing and player engagement and that need to be taken into account for game balancing. The most important factor is the **adjustment** itself (see 2.3.5 for the different adjustments that could be applied for game balancing). In this research only a subset of the adjustments has been studied. The adjustment determines whether, and how, the player's skills and player's performance will be affected (score adjustment versus asking a player to play with the non-dominant hand). The adjustment also enables the moderation of the influence of a player's performance on that of the opponent.

A second factor is the **design** of the adjustment. The design of the adjustment is important because it can enhance a player's experience and engagement. For example, a dynamic adjustment enhanced the sense of achievement of the players, which was important for player engagement (see case study in chapter 5). Also, a dynamic adjustment can be designed to adapt to players better. The design can also be used to adjust the degree of influence of the game adjustment on the players skills and players performance, and the degree of influence of a players performance on the opponents one. For example, by altering the table size dimensions in table tennis I modulated the style of play of the more skilled players from a more aggressive style of play to a more defensive style of play.

A third factor is the **characteristics** of the game. In case study in chapter 4 I have shown that game balancing should be designed different in different game worlds because of the differences in skill required to play the game in different game worlds. Future studies will be able to evaluate how other characteristics would affect the design of game balancing such as social games versus competitive games.

Finally, another factor that might be important to take into account for game balancing design, but whose study and evaluation has been out of the scope of this research, is the **motivation** of the players to play the game.

Game designers should take into account the interrelationship between all these factors for designing well-balanced and engaging games. Although this research has enhanced our understanding about this interrelationship, future work is necessary for a more comprehensive understanding.

8.4 Limitations

I reported the limitations of each case study in the relevant chapters. Here I summarise the main limitations of this research.

- The results have been obtained using the game of table tennis. Although the insights provided can be useful to other games, and the findings could be applied to other sports (see 8.5.1), further research is needed in order to validate and generalise the findings to other games.

- The research approach. As explained in 1.7, each case study built on the prior case study in order to get a greater understanding of particular findings. This has the benefit of providing a more in-depth understanding of particular aspects of game balancing, such as the relation of restricting players' performances and player engagement. However, the drawback of this approach is that it did not fully cover all the aspects of the game adjustment design for game balancing.

- The use of a questionnaire to evaluate player engagement (see the discussion in 3.3.1).

- The evaluation method for player engagement in the different table configurations in the case study in chapter 7 with players' ratings and interviews (see the discussion in 7.4.2).

- The sample size in each case study. Although the sample size was large enough to evaluate differences between conditions, it was not large enough to enable further investigation of other aspects of game balancing. For example, whether (and how) the results were influenced by the players' motivations in the practice of physical activity, and the effect of the size of the skill level differences between players.

- Self-assessment of players' skills. This was useful for recruiting and matching the participants prior to the experiment; however, it would have been better to test the participants' skill levels prior to the experiment for a better pairing of the participants.

8.5 Generalisability

It is important to understand how the findings and contributions of this research could be applied to other exertion games. Although further research is necessary, I describe how the findings could be applied to other sports. This section also aims to serve as an inspiration for further game balancing designs.

The findings and contributions made have been obtained through the study of the game of table tennis, in particular the traditional game where there is no virtual world in which to apply game balancing. In this context, a restriction of players' performances is often necessary for game balancing. The findings and contributions are mainly related to how to make this restriction on players' performances more engaging, and therefore the findings can be generalised more easily to similar contexts, such as squash. For this reason, I first describe how to generalise the findings to squash.

8.5.1 Generalising to squash

In chapter 4 I found that game adjustments might not always enhance player engagement because of the difficulties of controlling the impact of these adjustments on players' performances. This drawback is expected to be present in other games such as squash. In chapter 5 I derived a set of strategies to enhance player engagement, which could could be implemented in squash by first identifying the areas of the court that are more difficult (areas 2,3,4) and more easy (area 1) to return a ball from (see Figure 8.1). These areas were obtained through a study that identified where skilled players usually aim in competitive squash games [100].

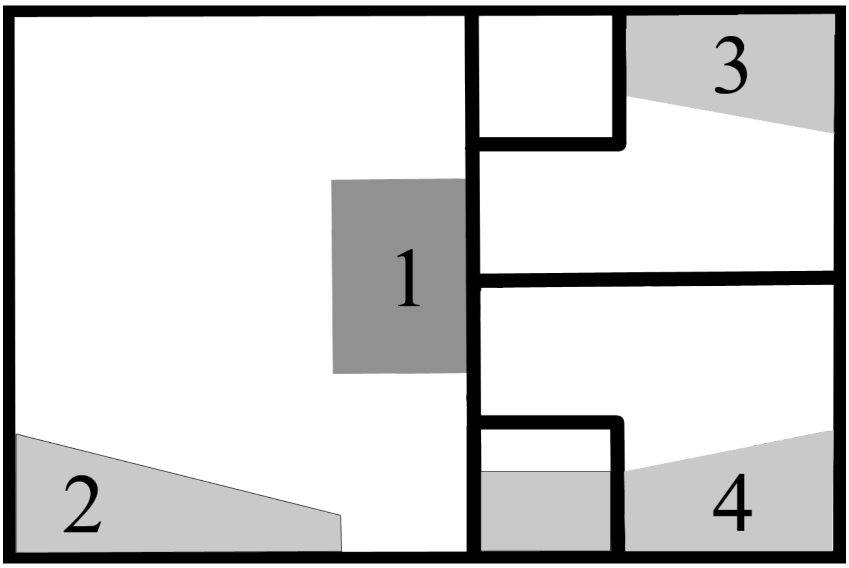

Figure 8.1: Squash court. Light gray zones (2,3,4) identify the optimal areas for ball placement [100]. The dark gray zone (1) identifies the area from which it is easier to return a stroke

From the different areas of the court in Figure 8.1, I describe one way we could implement each of the strategies derived in chapter 5:

- Support the training of useful sport skills: restrict the skilled players to use one or more of the light gray zones (2,3,4) (Figure 8.1).

- Set players' short-term goals: alter the squash court dynamically according to the difference in score between the players.

- Implement dynamic gameplay: reduce the court size dynamically to alter the players' actions and the level of challenge progressively. For example, from full court to require the more skilled players to hit the ball into zone 1 in Figure 8.1. This could help players in adapting to the game adjustments better and help game designers in having more control over the influence of the players' actions on the others' performances.

- Enhance players' sense of achievement: implement *achievable* short-term goals such as altering the game after each game point.

- Assist the less skilled players by altering the more skilled players' style of play: require the more skilled players to play only into zone 1 (see Figure 8.1).

Finally, the two ways I found in which the restriction on players' performances can contribute in game balancing (see chapters 6 and 7) can also be applied in squash:

- Altering the degree of challenge imposed by the restriction in place by altering the squash court dimensions.

- Altering the style of play induced on the more skilled players: by inducing a style of play that is more difficult to counter by the opponent (zones (2,3,4) in Figure 8.1), to one that is more easy to counter (zone 1 in Figure 8.1).

The relationship between the restriction on players' performances and player engagement in chapter 7 could also be expected in squash. As in table tennis, skilled players might find the gameplay more engaging when placing the ball in areas that are difficult for the opponent to counter. However, providing restrictions that extend the length of rallies can also be engaging and provide exercise benefits, specifically in a highly physical game such as squash.We could also use the additive effect of both ways of restricting players' performances for game balancing without the need to implement overly restrictive adjustments or to modulate the style of play too much when trying to assist the weaker players.

8.5.2 Generalising to other sports

In sports more different to table tennis, the game adjustment designs used in this research can be more difficult to apply. In table tennis I found adjusting the table to be useful because the ball-hit location on the table is important for scoring and for altering the players' styles of play. The table adjustment was used to (i) balance the game, (ii) moderate the influence of a player's actions on the opponent's performances, (iii) assist the weaker players by altering the style of play of the skilled ones, (iv) alter the degree of challenge in playing with an adjustment, and (v) enhance player engagement through setting new short term goals, providing dynamic gameplay and enhancing the players' sense of achievement. These effects of the table adjustment can be desirable for game balancing, but the approach to achieve them can be different in other non-parallel games.

As described in 8.5.1, the adjustment of the squash court could be used in the same way as the table adjustment in table tennis for game balancing and to implement the game design strategies outlined in this research. Similar game design adjustments could be applied in games such as tennis where the ball-hit location on the court is important for the gameplay and scoring. For other non-parallel games such as soccer or basketball where the use of the field is different, the design of game adjustments that implement the proposed game design strategies is not as straightforward.

In soccer there are a number of game alterations we can learn from disciplines like Game Sense [57] that allow us to restrict players' performances and alter the players' styles of play to assist the weaker players (team) in countering the stronger players (team). Game Sense includes game restrictions to modify the game; similarly, these restrictions can be used to our advantage for game balancing. For example Light [57] describes different game modifications in soccer, such as altering the number of players in a working space, altering the size of space in which the game is played, altering the number of passes the players must perform, restricting the distance between players, altering the size of the goals, or altering which foot the players must use to kick the ball. By applying some of these modifications we can alter the amount of challenge in playing with this restriction and encourage game mistakes as we did in table tennis. In addition, some of these alterations can also modify the style of play of a team and alter how easy it is for the opponent team to counter it. One could restrict the attacking areas or the number of passes to be made, which would induce a team to counter-attack or to play with a high ball possession.

In parallel games it can also be desirable to design game adjustments that succeed in (i), (iv) and (v) outlined above. However, (ii) would not be as important because there would be no need to moderate the influence of a player's actions on the other's performance. Regarding (iii), game adjustments could be designed to assist the weaker players [12], but in non-parallel games the assistance might need to pay more attention to altering the players' performances than parallel games because of the influence a player can have on his or her opponent.

An example of applying the game adjustments studied in a cycling digital game is as follows. In a cycling digital game where two players ride a static bicycle, digital technology could be used to alter the characteristics of the real bicycle (e.g. the pedal resistance) and the mappings from the real to the virtual bicycle in order to alter the challenge of riding the bicycle (players' physical efforts) and the challenge in controlling the virtual bicycle (players' skills). This can restrict players' performances and alter the amount of challenge of players. In addition we could moderate the attacks of the skilled players and how the less skilled players can counter them by altering the cycling route dynamically (e.g. type and slope of the terrain). For example, providing an easier terrain for weakest players to ride when the skilled players are attacking.

8.6 Future work

Future work can extend this research in the following directions:

- **Physical activity:** Investigate the relationship between game adjustments and their impact on physical activity. For example, we could investigate how physical activity is affected by the players' performance restriction. This would further our understanding of exertion game balancing design that not only enhances player engagement, but also provides the necessary physical exertion to players. This can be important in order to maximise the benefits of the practice of physical activity to people.

- **Players' skills:** I have shown there are game adjustments that can encourage the training of players' skills (e.g. game adjustments that encourage strokes that are difficult to counter). Future work can investigate the effectiveness of these game adjustments that can be used for game balancing in enhancing the players' skills. This research direction can overlap with disciplines such as Game Sense: an approach to coaching and physical education that uses modified games in order to encourage players to develop skills in a realistic context while enhancing tactical understanding [57]. This research direction would further our understanding of exertion game balancing design that enhances players' skills.

- **Skill level differences:** Investigate how the skill levels of the players, and the magnitude of the difference between their skills, influence these research findings such as the interrelation between game adjustments, game balancing and player engagement.

- **Player's motivation:** Investigate how the motivation of the players influence the research findings such as the interrelation between game adjustments, game balancing and player engagement.

- **Other non-parallel games:** Investigate how the game design strategies derived in this research (i.e. how we assisted the less skilled players by altering the opponents' styles of play and how we altered the degree of challenge in playing with a restriction) could be implemented in non-parallel games such as basketball and soccer, where the use of the field can be different to table tennis or squash (see 8.5.2).

- **Parallel games:** Similar to "other non-parallel games" we could investigate how the findings could be applied in parallel games, and investigate whether (and how) the relationship between the restriction on players' performances and player engagement derived in this research applies in parallel games.

8.7 Concluding remarks

Practising physical activity can provide health benefits, but people might not always find a suitable partner to play with. One reason for this is the skill difference between players, which can be moderated through game balancing.

Understanding game balancing that enhances player engagement is challenging owing to the many factors that can influence engagement [73]. In addition, game balancing in non-parallel games should be able to moderate the influence players have over their opponents. Designing game balancing experiences requires an understanding of the affect of game adjustments on game balancing and player engagement.

Four case studies have helped in providing an understanding of the interrelationship between game adjustments, game balancing and player engagement. The findings of this thesis were used to derive game design considerations (chapter 4), game design strategies (chapters 5 and 6) and an understanding of the relationship between the restriction on players' performances and player engagement. These research outcomes provide guidance for designing game balancing adjustments considering this interrelationship.

This research shows the benefits of digital technology in supporting game balancing design. The results contribute to HCI in understanding the use of digital technology in physical games such as sports. Although applying digital technology in sports can alter the traditional way of practising them, it can alter the players' experiences, which can be engaging for many people. This research builds on other work that started exploring the benefits of using digital technology in sports such as for enhancing social play. We are just starting to explore the potential of digital technology to provide engaging experiences for people who practise physical activity. This shows a promising future in the area HCI in sports that focuses on the players' experiences.

To conclude I hope this research can inspire those who aim to design well-balanced exertion games and can lead to novel and engaging balancing adjustments to existing exertion games. I also hope this research can inspire future research directions that can enhance our understanding of the design of exertion games in order to encourage people to practise and enjoy physical activity.

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Appendix A

Pre-questionnaires

A.1 Case study 1 reported in chapter 4

The participants were asked the following questions prior to the main experiment.

1. **Age:**

2. **Gender:**

Male Female

3. **Email or phone number:**

4. **Availability (days and times):**

5. How often do you play exertion games with the latest generation of video consoles that use motions sensors, such as Microsoft's Kinect, Nintendo Wii or Play Station Move?

Never	Less than Once a Month	Once a Month	2-3 Times a Month	Once a Week	2-3 Times a Week	Daily
○	○	○	○	○	○	○

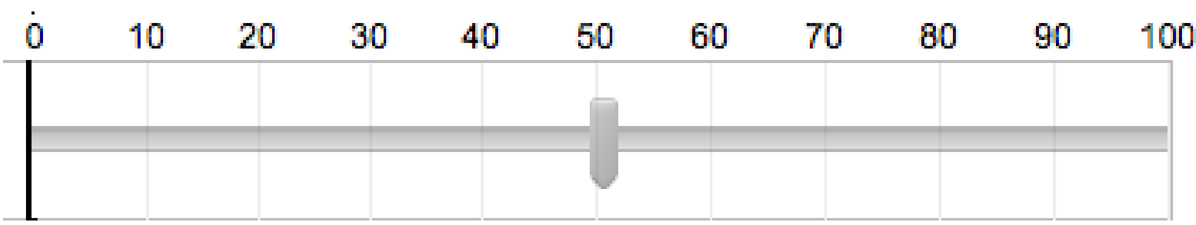
6. How often do you play table tennis?

Never	Less than Once a Month	Once a Month	2-3 Times a Month	Once a Week	2-3 Times a Week	Daily
○	○	○	○	○	○	○

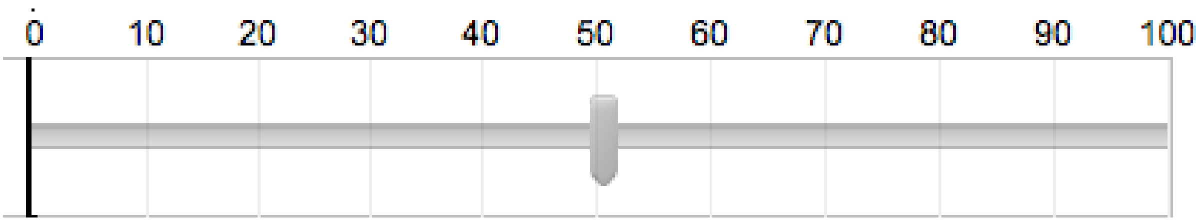
7. How often do you play digital table tennis game like the one in Wii Sports Resort from the Nintendo Wii?

Never	Less than Once a Month	Once a Month	2-3 Times a Month	Once a Week	2-3 Times a Week	Daily
○	○	○	○	○	○	○

8. Use the slider to rate your skill level in playing digital table tennis games like the one in Wii Sports Resort from the Nintendo Wii where 0 means "low skill level", 50 means "medium skill level" and 100 means "high skill level"



9. Use the slider to rate your skill level in playing in playing table tennis, where 0 means "low skill level", 50 means "medium skill level" and 100 means "high skill level"



A.2 Case studies 2-4 reported in chapters 5-7

The participants were asked the following questions prior to the main experiment.

1. Age:

2. Gender:

3. Email or phone number:

4. Availability (days and times):

5. **How often do you play table tennis?**

Never	Less than Once a Month	Once a Month	2-3 Times a Month	Once a Week	2-3 Times a Week	Daily
○	○	○	○	○	○	○

6. **Rate your skill level:**

Novice	Beginner	Competent	Proficient	Expert
○	○	○	○	○

7. **Have you ever been a member of a table tennis club?**

Yes	No
○	○

8. **How long have you been a member of a table tennis club?**

9. **Are you currently a member of a table tennis club?**

Yes	No
○	○

Appendix B

Questionnaire during experiment

B.1 Adapted engagement questionnaire from O'Brien et al. [74]

Rate (Answers: Strongly Disagree, Disagree, Neither Agree nor Disagree, Agree, Strongly Agree):

I lost myself in this game experience.
I was so involved in the game that I lost track of time.
I blocked out things around me when I was playing the game.
When I was playing, I lost track of the world around me.
The time I spend playing just slipped away.
I was absorbed in my game task.
During this gaming experience I let myself go.
I felt involved in the gaming task.
This gaming experience was fun.
I was really drawn into my gaming task.
Playing this game was worthwhile.
I consider my gaming experience a success.
My gaming experience was rewarding.
I would recommend playing this game to my friends and family.
The gaming experience did not work out the way I had planned.
I wanted to continue playing the game longer out of curiosity.
The game incited my curiosity.
I felt interested in the game.
I felt frustrated while playing this game.
I found the game interface confusing to use.
I felt annoyed while playing the game.

I felt discouraged while playing the game.

Playing the game was mentally taxing.

The game experience was demanding.

I felt in control of my gaming experience.

I could not do some of the things I wanted to do.

Appendix C

Semi-structured interviews

The following are examples of questions that participants were asked during the semi-structured interviews in the case studies in order to better understand each player's experience and players' engagement scores.

- Recall about the conditions played. Tell me something memorable, what do you remember that you found enjoyable? In which condition? Why?
- Tell me something you did not like, you did not find enjoyable when you were playing, in which condition? Why?
- Which condition do you prefer most? Why?
- Which condition do you prefer least? Why?
- How did the different game conditions affect your enjoyment or engagement?
- How did the different game conditions affect your experience? Why?
- Which aspects of the game do you think can be improved in each condition?
- Do you consider one game condition more unfair than the other(s)? Why? Did this influence your enjoyment in the game?
- Do you consider one game condition more challenging than the other(s)? Which one? Why? Did this influence your enjoyment in the game?
- Which game condition do you think helped bringing the players' skills closer? Why? How?
- Did one game condition influence your style of play? Which one? How? Why? Did this influence your enjoyment?

Appendix D

Ethics

D.1 Human ethics approvals

All case studies were approved by Human Ethics Committee. Reference numbers: HEC 2012/39/LR-PS (case study in chapter 4), HEC 2013/12/LR-PS (case study in chapter 5) , HEC 2014/08/LR-PS (case studies in chapters 6 and 7).